Fluids Pharmacotherapy & Management.

Presented by:

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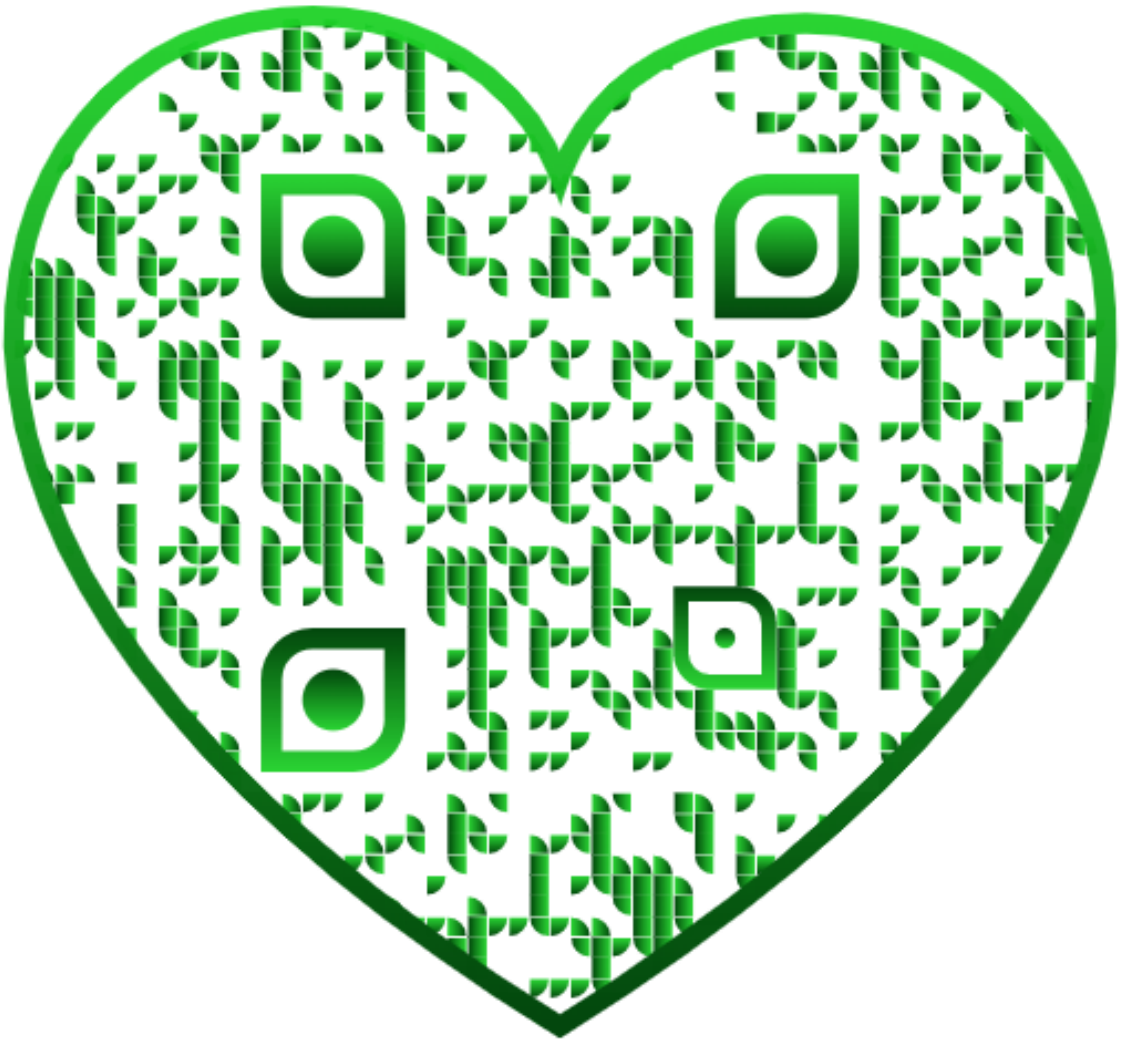


Presentation Agenda

1) Introduction to Fluids in Medicine
2) Understanding Body Fluid Compartments
3) Types of Fluids and Fluid Distribution & Kinetics
4) Fluid Monitoring & Safety
5) Fluid Management Strategies
6) Pediatric fluid management considerations
7) Disease-Specific Fluid Management

Introduction to Fluids in Medicine

❖ **The Biological & Medical Importance of Fluids**

- Essential for **Life & Homeostasis**
- Foundation of **Cellular Structure**
- Medium for **Transport & Signaling**
- Key to **Physiology & Disease**
- Advances in **Diagnostics & Research**

Aspect	Significance
Body Fluids	Blood, Interstitial Fluid, CSF
Cellular Function	Membranes, Buffers, Conductivity
Homeostasis	Renal & Endocrine Regulation
Disease Insight	Biomarkers & Fluid Imbalance

Introduction to Fluids in Medicine

- Fluids in medical practice are **administered intravenously or orasubstanceslly** to maintain or restore body fluid balance.

- Pharmacologic therapy complements fluid administration to manage fluid imbalances.

– Integrates with clinical practice to:
  - Restore **intravascular volume,** Correct **electrolyte disturbances &** Manage **acid-base abnormalities.**

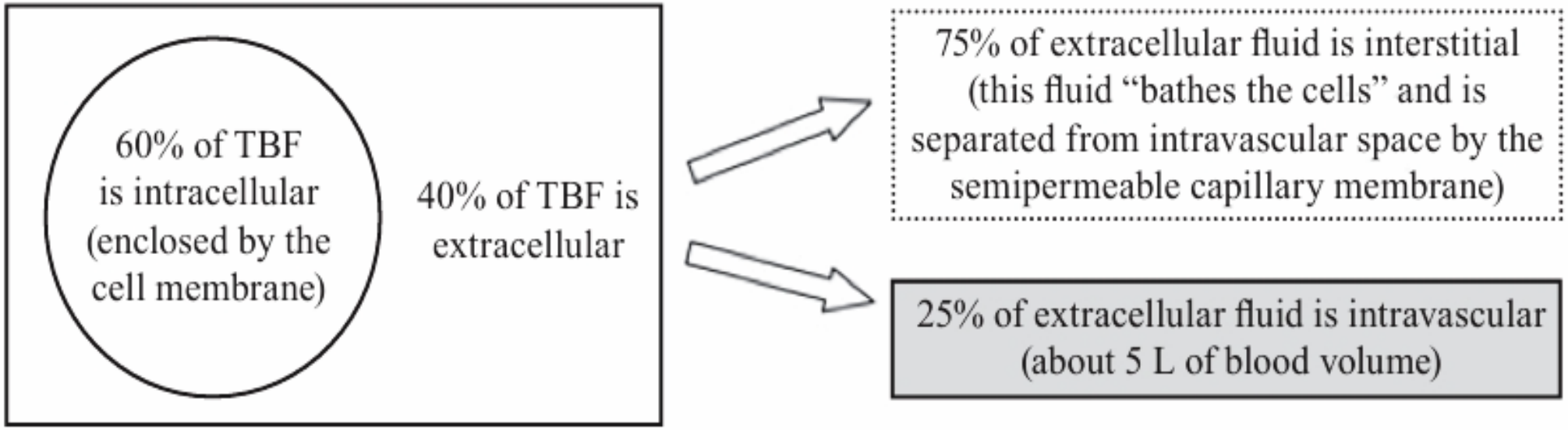
Physiology of Fluid Balance

- **Kidneys**: Regulate fluid volume and electrolyte excretion
- **Hormones**:
  - **ADH (Vasopressin)**: Promotes water reabsorption in kidneys
  - **Aldosterone**: Enhances sodium and water reabsorption
  - **ANP (Atrial Natriuretic Peptide)**: Promotes sodium and water excretion
- **Electrolytes**: Maintain osmotic balance and cellular function

INPUTE	OUTPUT
• Ingested liquid: 1500 ml	• Kidney: 1500 ml
• Ingested food: 800 ml	• Skin loss: 600 ml
• Metabolism: 200 ml	• GI: 100 ml
Total: 2500 ml/day	• Lung: 300 ml
	Total: 2500 ml

Body Fluid Composition and Compartments

Table 1.1 Average total body water as a percentage of body weight						
Age	**Adult male**	**Adult female**	**Elderly**	**Adult obese**	**Infant**	**Neonate**
Total body water (% of body weight)	60%	50%	50%	50%	70%	80%


60% of TBF is intracellular (enclosed by the cell membrane)
40% of TBF is extracellular
75% of extracellular fluid is interstitial (this fluid "bathes the cells" and is separated from intravascular space by the semipermeable capillary membrane)
25% of extracellular fluid is intravascular (about 5 L of blood volume)

Classification of Intravenous Fluids

A. Crystalloids: IV fluids containing water, electrolytes (Na^+, Cl^-), and in some types, other solutes.

Fluid	Key Components	Notes
• **0.9% NaCl (NS)**	Na^+, Cl^-	Standard isotonic resuscitation fluid
• **Lactated Ringer's RL**	Na^+, Cl^-, lactate, K^+, Ca^{2+}	Balanced electrolyte solution
• **Plasma-Lyte / Normosol-R**	Na^+, Cl^-, acetate, K^+, Mg^{2+}	pH-buffered solutions
• **D5W (5% Dextrose in Water)**	Dextrose (5g/100mL) → free water	*Not for resuscitation*

Body Fluid Composition and Compartments

Table 1.3 The electrolyte concentration of body fluids		
Electrolytes	**ECF (mEq/L)**	**ICF (mEq/L)**
Sodium	142.00	10.00
Potassium	4.30	150.00
Chloride	104.00	2.00
Bicarbonate	24.00	6.00
Calcium	5.00	0.01
Magnesium	3.00	40.00
Phosphate and sulfate	8.00	15.00

Table 1.4 Major ions in ECF and ICF		
	ECF	**ICF**
Major cation	Sodium	Potassium and magnesium
Major anion	Chloride and bicarbonate	Phosphate, sulfate and protein

Body Fluid Composition and Compartments

Table 1.6 Normal plasma electrolyte concentrations		
Electrolyte	**mEq/L**	**mmol/L**
Cations		
Sodium	136 to 145	136 to 145
Potassium	3.5 to 5.0	3.5 to 5.0
Calcium total*	4.5 to 5.6	2.2 to 2.6
Ionized*	2.2 to 2.6	1.05 to 1.3
Magnesium*	1.4 to 1.7	0.70 to 0.85
Anions		
Chloride	96 to 106	96 to 106
Bicarbonate	22 to 26	22 to 26
*Value in mg/dL: The normal values for total calcium and ionized calcium are 8.5-10.5 mg/dL and 4.3-5.3 mg/dL, respectively. The normal value of magnesium is 1.7–2.1 mg/dL.		

Classification of Intravenous Fluids

Table 3. Intravenous Fluid Comparison

Solution	Osmolality (mOsm/L)	Sodium (mEq/L)	Chloride (mEq/L)	Dextrose (mOsm/L)
Lactated Ringer's solution	273	130	109	None
0.9% isotonic NaCl (normal saline)	308	154	154	None
0.45% NaCl	154	77	77	None
5% dextrose in water	252	None	None	278
5% dextrose + 0.33% NaCl	378	50	50	278
5% dextrose + 0.225% NaCl	329	38.5	38.5	278
5% dextrose + 0.45% NaCl	432	77	77	278

Information modified from reference 1.
NaCl = sodium chloride.

Classification of Intravenous Fluids

A. Crystalloids:

Distribution After Infusion

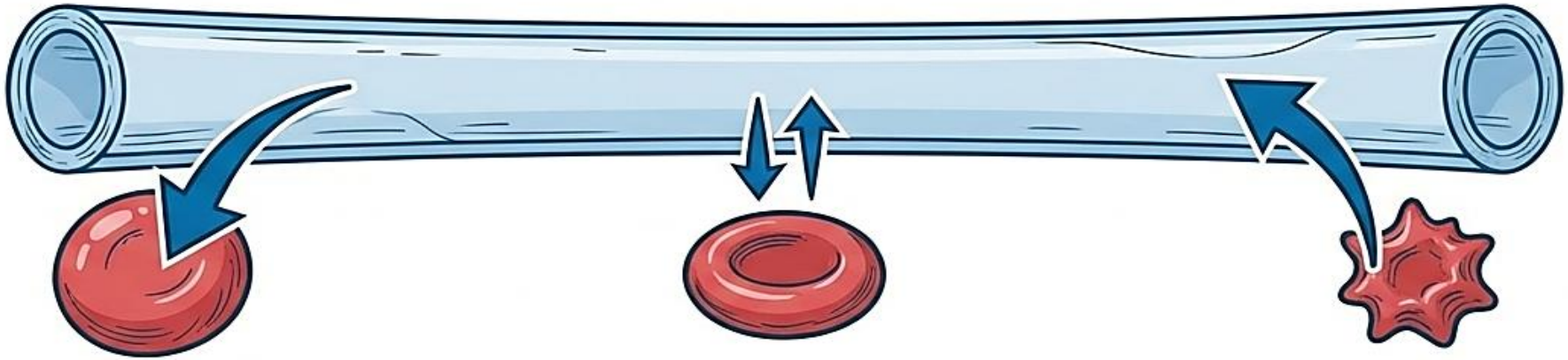
- **NS & Lactated Ringer's:**
  - Stay in **ECF** (extracellular fluid)
    - 75% → **interstitial fluid**, 25% → **intravascular**
  - Thus, **only ~250 mL remains intravascular** after 1L infusion

- **D5W (Isosmotic → becomes hypotonic):**
  - Rapid metabolism of glucose → free water
  - Distributes across **Total Body Water**:
    - 60% → **intracellular**, 40% → **extracellular**
    - Of ECF, 25% is intravascular → **~100 mL remains intravascular per 1L**

Classification of Intravenous Fluids

Understanding Crystalloids: The Role of Tonicity

Crystalloids are defined by their **tonicity**—the effective osmolality relative to plasma—which dictates how they shift water between body compartments.



Hypotonic

Water enters cells. Used for cellular hydration (e.g., hypernatremia).

Never for resuscitation.

Isotonic

No significant water shift. Expands extracellular volume (intravascular and interstitial).

The foundation of resuscitation.

Hypertonic

Water exits cells. Used for specific, critical conditions like cerebral edema or severe hyponatremia.

High-risk.

Key Examples:

- **Isotonic:** 0.9% NaCl, Lactated Ringer's, Plasma-Lyte
- **Hypotonic:** 0.45% NaCl, D5W (in the body)
- **Hypertonic:** 3% NaCl

Body Fluid Composition and Compartments

Table 1. Distribution of Intravenous Fluid

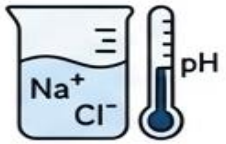
Intravenous Fluid	Infused Volume (mL)	Equivalent Intravascular Volume Expansion (mL)
Normal saline	1000	250
Lactated Ringer solution	1000	250
Normosol-R and Plasma-Lyte	1000	250
5% Dextrose	1000	100
Albumin 5%	500	500
Albumin 25%	100	500
Hydroxyethyl starch 6%	500	500

Classification of Intravenous Fluids

Isotonic Crystalloid Profile: 0.9% Normal Saline (NS)

Composition & Properties

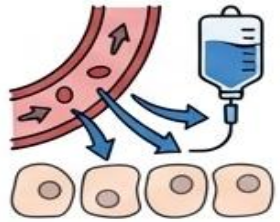
Composition: Na^+ 154 mEq/L, Cl^- 154 mEq/L
Osmolarity: ~308 mOsm/L (Isotonic)
pH: ~5.5 (Acidic)
Key Feature: Supraphysiologic chloride content compared to plasma (~100 mEq/L).



Mechanism & Distribution

Expands the Extracellular Fluid (ECF) with no major shift into cells.

Approximately 25% of the infused volume remains intravascular.



Core Indications

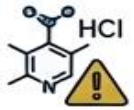
Fluid Resuscitation: First-line for shock, sepsis (30 mL/kg bolus), and dehydration.

Medication Diluent: Compatible with most IV drugs (e.g., required for Phenytoin).

Blood Product Co-infusion: The *only* recommended fluid for priming lines or diluting blood products.

Critical Cautions

Hyperchloremic Metabolic Acidosis: Risk with large volumes due to high chloride load.



Fluid Overload: Use with caution in heart failure, renal failure, and edematous states.

Acute Kidney Injury: Some studies suggest higher risk compared to balanced solutions in large volumes.

Clinical Pearl: The universal workhorse for volume and blood transfusions, but its high chloride load makes balanced fluids a better choice for massive resuscitation.

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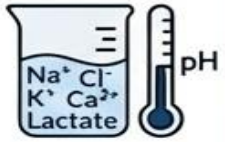
Classification of Intravenous Fluids

Isotonic Crystalloid Profile: Lactated Ringer's (LR)

Composition & Properties

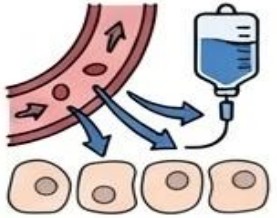


Composition: Na^+ 130, Cl^- 109, K^+ 4, Ca^{2+} 3, Lactate 28 mEq/L
Osmolarity: ~273 mOsm/L (Isotonic)
pH: ~6.5
Key Feature: Contains lactate, a buffer precursor metabolized to bicarbonate.

Mechanism & Distribution

Distributes in the ECF similarly to NS.

The metabolism of lactate provides an alkalinizing effect, counteracting metabolic acidosis.



Core Indications

Large-Volume Resuscitation: Preferred fluid in trauma, burns (Parkland formula), and sepsis to avoid acidosis.

Perioperative Fluid: Widely used during and after surgery.

GI Fluid Loss Replacement: Useful for replacing bicarbonate-rich losses from diarrhea or fistulas.

Critical Cautions

Blood Transfusions: DO NOT co-infuse with blood. The calcium can bind to citrate anticoagulant and cause clotting in the IV line.

Severe Liver Disease: Lactate metabolism may be impaired.

Hyperkalemia: Use with caution due to its potassium content (4 mEq/L).

Clinical Pearl: A more physiologic choice for replacing GI losses and for large-volume resuscitation, but remember: LR and blood products **must never mix.**

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Classification of Intravenous Fluids

Advanced Isotonic Fluids: Plasma-Lyte

Plasma-Lyte and similar solutions are "next-generation" balanced crystalloids designed to be even more physiologic than LR. They contain **no calcium** and use alternative buffers.

Plasma-Lyte A Profile

- **Composition:** Na^+ 140, K^+ 5, Mg^{2+} 3, Cl^- 98 mEq/L

- **Buffers:** Acetate (27 mEq/L) and Gluconate (23 mEq/L)
- **pH:** ~7.4 (Physiologic)
- **Key Feature:** Contains no calcium, making it compatible with blood products.

Clinical Advantages & Disadvantage

Clinical Advantages over LR/NS

- **Blood Compatibility:** Safe to co-infuse with blood transfusions.
- **No Lactate:** A preferred balanced solution in patients with severe liver failure or lactic acidosis.
- **Physiologic pH:** The most neutral fluid, causing minimal acid-base disturbance.

Primary Disadvantage

- **Cost:** Significantly more expensive than NS or LR.

Clinical Pearl: The 'does-it-all' balanced crystalloid: **compatible with blood**, **safe in liver failure**, and **pH neutral**. Its primary limitation is cost.

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Classification of Intravenous Fluids

The 'Free Water' Fluid: D5W (5% Dextrose in Water)

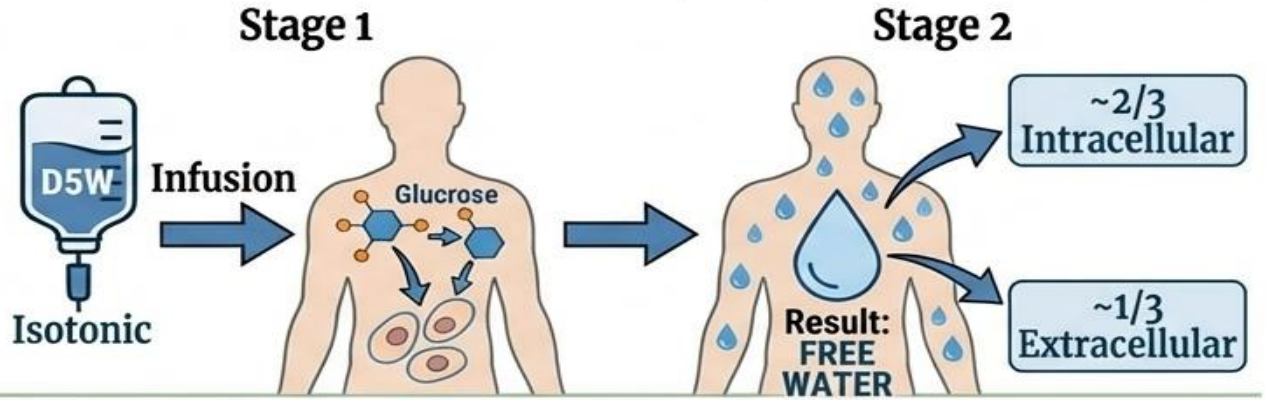
Composition & Properties

- **Composition:** 50 g/L Dextrose (Glucose), No electrolytes.
- **Osmolarity:** ~252 mOsm/L (Isotonic in the bag)
- **Key Feature:** Provides ~170 kcal/L of energy.

Core Indications

- **Free Water Replacement:** Treatment of hypernatremia.
- **Medication Diluent:** Required for drugs unstable in saline (e.g., Amphotericin B, Oxaliplatin).
- **Maintenance Fluid Component:** Often combined with saline (e.g., D5½NS) to prevent ketosis in NPO patients.

Mechanism: 'Isotonic in the Bag, Hypotonic in the Body'



Critical Cautions

- **DO NOT USE FOR RESUSCITATION:** It will not expand intravascular volume and can worsen hypotension.
- **Avoid in Head Injury:** Can increase intracranial pressure and worsen cerebral edema.
- **Risk of Hyponatremia:** Can dangerously dilute serum sodium if given in excess or in patients with SIADH.

Clinical Pearl: Think of D5W as an IV form of drinking water. It is a vehicle for free water delivery, not for volume expansion.

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Classification of Intravenous Fluids

The Crystalloid Toolkit: Comparing the Workhorses

	0.9% NaCl (Normal Saline)	Lactated Ringer's (LR)	5% Dextrose in Water (D5W)
Composition *Source Serif Pro regular*	Na+ 154, Cl- 154 mEq/L. Osmolarity 308 mOsm/L.	Na+ 130, Cl- 109, K+ 4, Ca^{2+} 3, Lactate 28 mEq/L. Osmolarity 273 mOsm/L.	Dextrose 50 g/L. Osmolarity 252 mOsm/L.
Intravascular Expansion *per 1000 mL infused*	~250 mL remains intravascular.	~250 mL remains intravascular.	~100 mL remains intravascular.
Key Advantages	Inexpensive, compatible with most drugs/blood.	More "physiologic" or "balanced," lactate buffer helps prevent acidosis.	Delivers "free water" to correct hypernatremia.
Safety & Pitfalls	**Safety Alert** Large volumes can cause hyperchloremic metabolic acidosis and potential AKI.	**Safety Alert** Contains Calcium (Incompatible with Ceftriaxone and citrated blood) and Potassium (Use cautiously in hyperkalemia/renal failure).	**Safety Alert** DO NOT use for resuscitation. Can worsen cerebral edema in neurologic injury.

Classification of Intravenous Fluids

Specialized Crystalloids: Hypotonic and Hypertonic Saline

Hypotonic Saline (0.45% NaCl)

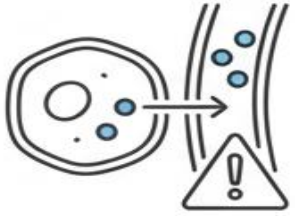
- **Also Known As:** Half-Normal Saline
- **Mechanism:** Provides both free water and a small amount of salt. Water shifts into cells.
- **Primary Use:** Treating hypernatremic dehydration, where both free water and some volume are needed. A common component of maintenance fluids (e.g., D5½NS).

⚠ CRITICAL WARNING

Not for resuscitation. Avoid in patients with or at risk for cerebral edema or hyponatremia.

Hypertonic Saline (3% NaCl)

- **Mechanism:** Extremely high osmolarity (~1026 mOsm/L) pulls water *out of* cells and into the intravascular space.
- **Primary Uses:**
  1. **Severe, Symptomatic Hyponatremia:** (e.g., seizures, coma) to rapidly increase serum sodium.
  2. **Intracranial Hypertension:** Reduces cerebral edema by dehydrating brain tissue.



⚠ CRITICAL WARNING

A high-risk medication. Requires central line administration (for continuous infusion), frequent sodium monitoring (q2-4h), and a slow, controlled rate of correction to **prevent Osmotic Demyelination Syndrome (ODS)**.

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Classification of Intravenous Fluids

B. Colloids

- **Definition:** Large molecules (**proteins, starches**) that exert oncotic pressure and stay primarily in the **intravascular space**.

Types:

- **Natural:** Packed RBCs, plasma, albumin (5%, 25%), plasma protein fraction.
- **Synthetic:** Dextrans, hydroxyethyl starch (HES).

Distribution & Effects:

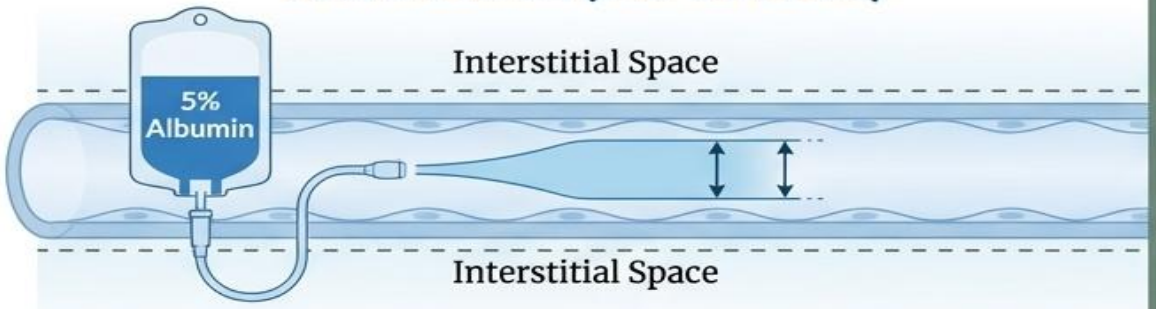
- **Standard colloids (e.g., 5% albumin):** 500 mL → ~500 mL intravascular expansion.
- **25% albumin:**
  - Hyperoncotic; pulls fluid from IS space → **100 mL** → **~500 mL** expansion.
  - **Avoid in fluid resuscitation** due to risk of IS dehydration.
  - **Use in fluid redistribution** (e.g., ascites, pleural effusion).
- **Risks with synthetic colloids:**
  - **HES and dextran** linked to **coagulopathy**, **AKI**, and increased **mortality** in ICU patients

Classification of Intravenous Fluids

Colloid Profile: Human Albumin (5% and 25%)

Albumin is the primary natural colloid used clinically. Its effect depends entirely on its concentration.

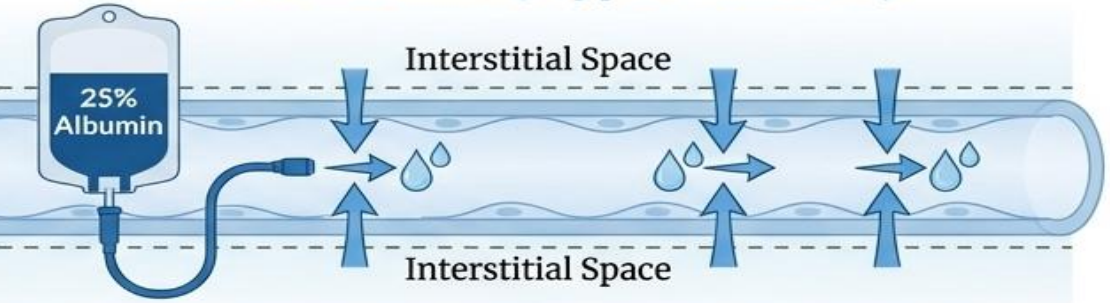
5% Albumin (Iso-oncotic)



Mechanism: Acts as a plasma volume expander. 500 mL infused ≈ 500 mL of intravascular volume expansion. It stays in the vasculature longer than crystalloids.

Use: Second-line for shock resuscitation after large-volume crystalloids have failed.

25% Albumin (Hyper-oncotic)



Mechanism: Pulls 3-4 mL of interstitial fluid into the vasculature for every 1 mL infused. Mobilizes third-spaced fluid.

Use: To reduce edema and restore volume in specific conditions.

Evidence-Based Indications

- **Large-Volume Paracentesis (>5L):** Prevents circulatory collapse.
- **Spontaneous Bacterial Peritonitis (SBP):** Reduces incidence of renal failure.
- **Hepatorenal Syndrome (HRS):** Used in combination with vasoconstrictors.

Clinical Pearl

Use albumin for its oncotic properties, not just as a volume expander. It is a targeted therapy for specific disease states, primarily in cirrhosis.

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Classification of Intravenous Fluids

Synthetic Colloids: A Cautionary Tale of Declining Use

Synthetic colloids like Hydroxyethyl Starches (HES) and Dextrans were once popular alternatives to albumin for volume expansion. However, major clinical trials have revealed significant safety risks, leading to a dramatic decline in their use.

- **Hydroxyethyl Starch (HES):** e.g., Hetastarch, Voluven
- **Dextrans:** e.g., Dextran 40, Dextran 70

Key Safety Concerns & Contraindications

⚠ **Acute Kidney Injury:** HES is associated with an increased risk of AKI requiring dialysis, especially in septic and critically ill patients. **(FDA Black Box Warning)**

⚠ **Coagulopathy:** Both HES and Dextrans interfere with clotting factors and platelet function, increasing bleeding risk.

⚠ **Anaphylaxis:** Dextrans carry a notable risk of severe anaphylactoid reactions.

⚠ **Increased Mortality:** Landmark trials (e.g., CHEST, VISEP) showed no benefit and potential harm with HES in ICU patients.

Bottom Line

The use of synthetic colloids is now highly restricted and contraindicated in critically ill patients, sepsis, and renal impairment due to a poor risk-benefit profile.

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Principles of Fluid Management

Assess:

Patient's fluid status, including vital signs, urine output, and lab values

Choose

Appropriate type and amount of fluid

Administer:

Fluid at the correct rate

Monitor:

Patient response and adjust fluid therapy as needed

Proper Monitoring of Fluid Therapy

Intravenous fluids are a potent medical intervention. Proper monitoring is crucial for maintaining physiological balance, ensuring tissue perfusion, and mitigating severe risks of hypovolemia and hypervolemia.

Bedside Clinical Assessment

Monitor Hemodynamic Vital Signs

- Target MAP ≥65 mmHg
- Watch for Tachycardia. (HR >90 bpm)

Abnormal (Threshold for Action):
MAP <65 mmHg; HR >90 bpm; RR >20 bpm

Assess End-Organ Perfusion

- **Urine Output** <0.5 mL/kg/hr
- **Capillary Refill Time** >2 seconds
- **Altered Mental Status** signal hypoperfusion

Evaluate Respiratory Status

Tachypnea is an early warning sign

Laboratory & Physical Surveillance

Track Serum Electrolytes and Renal Function

- **Na+** for water balance
- **Cl-** for acidosis risk
- **Creatinine** for acute kidney injury

Measure Daily Body Weight

Most sensitive indicator of fluid change; Acute gain of a3% suggests fluid overload

Maintain a Fluid Balance Chart

Accurately record all inputs and outputs, mindful of insensible losses (e.g., fever)

Advanced Monitoring Tools

Use Dynamic Measures over Static Ones

VS

Passive Leg Raise (PLR) is preferred over **Central Venous Pressure (CVP)** to predict fluid responsiveness

Utilize Point-of-Care Ultrasound (POCUS)

Assess the inferior Vena Cava (IVC); small, collapsing IVC suggests a fluid deficit

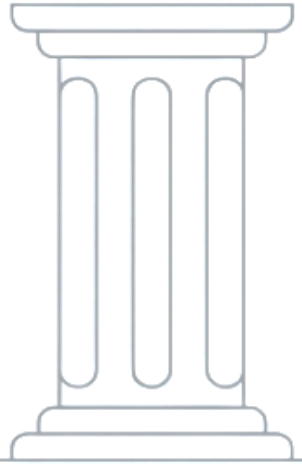
Differentiate Treatment Based on Findings

- Signs of hypovolemia may require a fluid challenge
- Signs of overlead require fluid restriction or diuretics

Indications for Fluid Therapy

Fluid therapy is tailored to the patient's specific clinical state, falling into one of three core categories. Understanding the goal of each pillar is crucial for appropriate management.

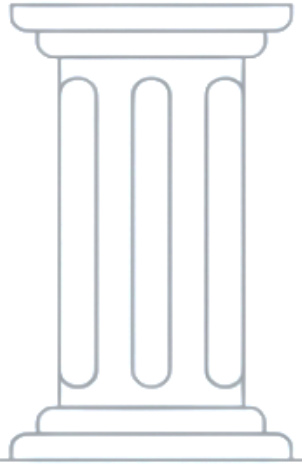
Maintenance



Patient State: Stable, but NPO (unable to take orally).

Goal: Preserve water and electrolyte balance. Fulfill daily physiologic needs.

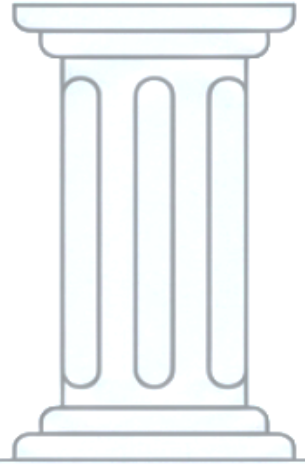
Replacement



Patient State: Evidence of fluid deficit (e.g., dehydration, ongoing losses).

Goal: Correct existing water and electrolyte deficits.

Resuscitation



Patient State: Severe hypovolemia or shock.

Goal: Rapidly restore circulatory volume to maintain organ perfusion.

1- Maintenance intravenous fluids

- **Indication:** Patients **unable to tolerate oral fluids** (e.g., NPO, critically ill)
- **Goal:** **Prevent dehydration** and **maintain fluid & electrolyte balance**

- **Administration:** Continuous infusion via **peripheral or central IV catheter**
  - Fluid type: Typically, **D5W + 0.45% NaCl** with **potassium chloride** (20–40 mEq/L)

- **Common Methods for Estimating Daily Volume:**

✓ **For children:** **100 mL/kg** for the **first 10 kg**, **50 mL/kg** for the **next 10–20 kg, 20 mL/kg** for **>20 kg.**

✓ **For adults:** **20–40 mL/kg/day**, adjusted for clinical condition.

✓ Adjustments based on patient's clinical condition (output, insensible losses, fever, etc.)

2- Water and Electrolyte Maintenance

❖ Water Needs in Hospitalized Patients:

- ✓ **Normal Requirements:** <1 liter of electrolyte-free water/day
- ✓ **Increased needs:** Fever, burns, tachypnea, surgical drains, GI losses
- ✓ **Decreased needs:** Oliguric kidney failure, edematous states, SIADH
- ✓ **Sodium Balance:** Best estimated by serum sodium concentration, but clinical signs of volume overload or depletion must be monitored.

➢ **Electrolyte Losses:** Primarily sodium and potassium via urine

Electrolyte Balance and Fluid Adjustments

Maintenance fluid requirements are not static. Clinicians must continuously assess patient factors that alter water needs.

Factors Increasing Water Requirements

- **Fever:** Increase by 100-150 mL/day for each degree Celsius over 37°C.
- **Sweating & Burns:** Significant insensible losses.
- **Tachypnea:** Increased respiratory water loss.
- **Surgical Drains & GI Losses:** Direct volume and electrolyte depletion.
- **Polyuria:** As seen in diabetes insipidus.

Factors Decreasing Water Requirements

- **Oliguric Kidney Failure:** Inability to excrete water.
- **Humidified Air (Ventilator):** Reduces respiratory losses.
- **Edematous States:** Heart failure, cirrhosis.
- **Hypothyroidism:** Reduced metabolic rate.
- **SIADH:** Nonosmotic ADH release leads to water retention.

Monitoring

The serum sodium concentration is the best estimate of water balance.

- **If Serum Na+ Falls:** Use a more concentrated solution (e.g., Isotonic Saline).
- **If Serum Na+ Rises:** Use a more dilute solution (e.g., Quarter-Isotonic Saline or add D5W).

2- Replacement Fluid Therapy:

- **The goal of replacement therapy is to correct existing abnormalities in volume status and/or serum electrolytes.**

- **Volume Deficit:** Estimated **by pre- and post-deficit weight**, **clinical parameters** like **BP, urine sodium concentration**, and **hematocrit**.

- **Rate of Correction:**
- ✓ **Severe deficits (hypovolemic shock):** Rapid fluid resuscitation (1-2L isotonic fluids)
- ✓ **Mild-to-moderate deficits:** Fluid administration greater than fluid losses (urine, insensible losses)

Maintenance Fluids:
- Essential for water/electrolyte balance when oral intake is inadequate

Replacement Fluids:
- Correct existing deficits and maintain volume

2- Replacement Fluid Therapy:

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- **Rate of Correction:**

✓ **Severe deficits (hypovolemic shock):** Rapid fluid resuscitation (1-2L isotonic fluids)

✓ **Mild-to-moderate deficits:** Fluid administration greater than fluid losses (urine, insensible losses)

2- Replacement Fluid Therapy:

Correct existing abnormalities in volume status and/or serum electrolytes resulting from gastrointestinal, urinary, skin losses, bleeding, or third-space sequestration.

Assessing the Volume Deficit

There is no perfect formula. Assessment is clinical.

Best Estimate

Change in body weight. (1 kg weight loss ≈ 1 L fluid deficit).

Clinical Parameters

- Blood Pressure (Hypotension, Orthostasis)
- Jugular Venous Pressure (JVP)
- Urine Output
- Skin Turgor & Mucous Membranes

Laboratory Parameters

- **Urine Sodium (UNa):** A UNa < 15 mEq/L suggests the kidney is sensing volume depletion and conserving sodium.
- **Hematocrit:** Rises with hemoconcentration (if no bleeding).
- **Serum Lactate:** Elevated in cases of poor perfusion.

Executing Replacement: Rate & Fluid Choice

Rate of Replacement is Dictated by Severity

Mild to Moderate Hypovolemia

Rapid resuscitation is not necessary.

Goal: *Induce positive fluid balance.*

Administer fluid at a rate 50 to 100 mL/hour *greater than* the rate of ongoing losses (urine + insensible + GI losses).

Severe Hypovolemia / Shock

Requires immediate, rapid fluid administration.

Goal: *Restore tissue perfusion quickly.*

Regimen: See Resuscitation Pillar.

Choosing the Replacement Fluid

The composition of the replacement fluid should be guided by the type of fluid lost and concurrent electrolyte disorders.

Common starting point

Common starting point: Isotonic (0.9% NaCl) or one-half isotonic (0.45% NaCl) saline.

Specific Scenarios

Hypernatremia: Use hypotonic solutions (e.g., 0.45% NaCl, D5W).

Hyponatremia: Use isotonic or hypertonic saline.

Metabolic Acidosis (e.g., Diarrhea): Consider adding bicarbonate or using a buffered crystalloid like Lactated Ringer's.

Hemorrhage: Use blood products.

3- Fluid Resuscitation Therapy

Pillar 3: Emergency Resuscitation — Restoring Perfusion in Shock

Definition

The rapid administration of intravenous fluids to restore or maintain circulatory volume during severe hypovolemia or shock.

Objective

Quickly administer a large fluid volume to stabilize hemodynamics, thereby restoring tissue perfusion and oxygen delivery without causing harm from fluid overload.

Key Indications

- Severe Hypovolemia
- Sepsis & Septic Shock
- Trauma & Hemorrhage
- Severe Burns
- Perioperative Volume Loss

- **Initial Target:** Achieve a Mean Arterial Pressure (MAP) of ≥ 65 mmHg.
- **Critical Imperative:** Delay in therapy can lead to ischemic injury and irreversible multiorgan system failure. Treat the underlying cause of shock simultaneously.

3- Fluid Resuscitation Therapy

- **Intravascular fluid depletion** can occur **because of shock (hypovolemic or septic shock),** and it is **associated with reduced cardiac function** and **organ hypoperfusion**.

- **Signs or symptoms usually occur when about 15% (750 mL) of blood volume is lost** (e.g., hemorrhage) or **shifts out of the intravascular space** (e.g., septic shock).

- **Fluid resuscitation is indicated for patients with signs or symptoms of intravascular volume depletion**.

3- Fluid Resuscitation Therapy

❖ Signs of Intravascular Volume Depletion

Box 1. Signs and Symptoms of Intravascular Volume Depletion

Tachycardia (HR > 100 beats/minute)
Hypotension (SBP < 80 mm Hg)
Orthostatic changes in HR or BP
Increased BUN/SCr ratio > 20:1
Dry mucous membranes
Decreased skin turgor
Reduced urine output
Dizziness
Improvement in HR and BP after a 500- to 1000-mL fluid bolus

BP = blood pressure; BUN = blood urea nitrogen; HR = heart rate; SBP = systolic blood pressure; SCr = serum creatinine.

3- Fluid Resuscitation Therapy

- **The goal of fluid resuscitation** is **to restore intravascular volume** and to **prevent organ hypoperfusion**.

- Because intravascular volume depletion **can cause organ dysfunction** and **death, prompt resuscitation is necessary**.
  a. Intravenous fluids are **infused rapidly**, **preferably through a large-bore catheter.**
  b. Intravenous fluids are **administered as a 500- to 1000-mL bolus**, **(~30 mL/kg in septic patients)** after which the patient is reevaluated; this process **is continued as long as signs and symptoms of intravascular volume depletion are improving.**

Lactated Ringer's vs Normal Saline in Fluid Resuscitation

- **Crystalloids are recommended for fluid resuscitation in hypovolemia**

a. **Lactated Ringer solution is historically preferred in surgery and trauma patients**, but **no evidence suggests superiority over normal saline** for fluid resuscitation in these settings.

b. **The lactate in lactated Ringer solution** is **metabolized to bicarbonate**, and it can **theoretically be useful for metabolic acidosis**; however, **lactate metabolism is impaired during shock**. Thus, lactated Ringer solution may be an **ineffective source of bicarbonate**.

Lactated Ringer's vs Normal Saline in Fluid Resuscitation

The Current Consensus

Isotonic, balanced crystalloids are the preferred first-line resuscitation fluids for most critically ill patients.

What are Balanced Crystalloids?

Solutions formulated to more closely mirror the electrolyte composition and pH of human plasma.

- **Examples:** Lactated Ringer's (RL), PlasmaLyte.
- **Key Feature:** Contain a lower chloride concentration and a buffer (lactate, acetate) that is metabolized to bicarbonate.

The Guideline Shift

Surviving Sepsis Campaign (2021)

Suggests using balanced crystalloids *instead of* normal saline.

European Society of Intensive Care Medicine (ESICM) (2024)

Recommends using balanced crystalloids *instead of* normal saline in severe volume depletion, sepsis, or kidney injury.

**Producer Note: The following slides will unpack the evidence behind this recommendation.*

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Lactated Ringer's vs Normal Saline in Fluid Resuscitation

Why the Shift? The Physiology of Fluid Choice

Feature	0.9% Normal Saline (NS)	Balanced Crystalloids (RL, PlasmaLyte)
Chloride (Cl^-)	**154 mEq/L** (Supraphysiologic)	**98-109 mEq/L** (Physiologic)
Buffer	None	Yes (Lactate or Acetate)
Strong Ion Difference (SID)	**0** (Acidifying effect)	**28-50** (Closer to plasma SID of 40)
Primary Risks	**Hyperchloremic Metabolic Acidosis:** Infusion of high chloride load with SID of 0 decreases plasma SID, leading to acidosis.	Hypotonicity (RL), Metabolic Alkalosis (with large volumes).
Impact on Kidneys	**Acute Kidney Injury (AKI):** Hyperchloremia can cause renal afferent arteriolar vasoconstriction ("Tubuloglomerular Feedback"), reducing GFR.	Generally lower risk of AKI.
Impact on Potassium	Can worsen hyperkalemia due to acidosis-induced potassium shift out of cells.	Safer in hyperkalemia; corrects acidosis, promoting K+ shift into cells. The 4 mEq/L of K+ in RL is not sufficient to cause hyperkalemia.

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Lactated Ringer's vs Normal Saline in Fluid Resuscitation

Weighing the Evidence: Key Clinical Trials

The debate between saline and balanced crystalloids has been tested in several large randomized controlled trials (RCTs).

Evidence Suggesting Superiority of Balanced Crystalloids

- **SMART Trial (NEJM 2018):** 15,802 critically ill adults. Use of balanced crystalloids resulted in a lower rate of the composite outcome of death, new renal-replacement therapy, or persistent renal dysfunction vs. saline.
- **SALT-ED Trial (NEJM 2018):** 13,347 non-critically ill adults. Use of balanced fluids resulted in a lower rate of the same composite outcome.

Evidence Suggesting No Difference

- **BaSICS Trial (JAMA 2021):** 11,000 critically ill patients. No significant difference in 90-day mortality or AKI. Limitation: smaller median fluid volumes administered.
- **PLUS Study (NEJM 2022):** 5,000 critically ill patients. Balanced solution did not reduce mortality or kidney injury vs. saline.

The Synthesis: Meta-Analyses & Guidelines

Systematic reviews (e.g., Hammond NE et al., NEJM Evid 2022; Zampieri et al., Lancet 2024) and major guidelines (Sepsis, ESICM) favor balanced solutions, concluding that given the low risk of harm and real possibility of benefit, their use is a prudent choice.

Lactated Ringer's vs Normal Saline in Fluid Resuscitation

The Right Fluid for the Right Patient: A Clinical Guide

The choice of crystalloid is not absolute; it should be tailored to the patient's specific clinical context.

When to Prefer BALANCED CRYSTALLOIDS (RL, PlasmaLyte)

- **Sepsis & Septic Shock:** Guideline-recommended first choice.
- **Large Volume Resuscitation (>2L):** To avoid hyperchloremic acidosis.
- **Patients at risk for/with AKI:** To mitigate the risk of chloride-induced renal vasoconstriction.
- **Metabolic Acidosis:** The buffer helps correct acidosis (e.g., DKA, pancreatitis, diarrhea).
- **Hyperkalemia:** Contrary to myth, RL is safer than NS as it corrects acidosis, which drives K+ intracellularly.

When to Prefer NORMAL SALINE (0.9% NaCl)

- **Traumatic Brain Injury (TBI):** To avoid even mild hypotonicity. RL has an osmolality of 273 mOsm/L, which can worsen cerebral edema.
- **Metabolic Alkalosis with Hypochloremia:** Provides the chloride needed to correct the alkalosis (e.g., from severe vomiting).
- **Co-infusion with Blood Products:** RL contains calcium, which can chelate the citrate anticoagulant in packed red blood cells, leading to clotting in the IV line.
- **Severe Hyponatremia:** Where a higher sodium concentration is desired.

Crystalloids vs Colloids in Fluid Resuscitation

- **No significant difference** in time to achieve resuscitation or patient outcomes **between crystalloids and colloids.**
- **Crystalloids are the preferred first-line fluid** due to **lower cost** and **fewer adverse effects.**
- **Colloids are not superior to crystalloids and are associated with: Higher cost and Risk of adverse effects**

Crystalloids vs Colloids in Fluid Resuscitation

The Verdict

Crystalloids are the recommended first-line therapy for fluid resuscitation. Colloids are a second-line therapy for selective use.

Crystalloids

(e.g., 0.9% Saline, Lactated Ringer's)

- **Physiology:** Sodium-rich solutions that distribute throughout the extracellular fluid (ECF). Only ~25% of infused volume remains intravascular.
- **Clinical Evidence:** Multiple large trials (e.g., SAFE, CRISTAL) and guidelines (Surviving Sepsis, ESICM) support their use as first-line agents. No consistent survival benefit has been shown for colloids over crystalloids.
- **Advantages:** Inexpensive, readily available, reaction-free.

Colloids

(e.g., Albumin, Starches)

- **Physiology:** Large molecules that remain primarily in the intravascular space, leading to more potent and rapid volume expansion per mL infused.
- **Clinical Evidence:** Despite physiological advantages, trials have not demonstrated superior outcomes.
- **Disadvantages:** Expensive, potential for adverse effects (especially synthetic colloids).

Crystalloids vs Colloids in Fluid Resuscitation

❖ When to Use Colloids:

➢ After Crystalloid Failure:

- When **4-6 L of crystalloids** fail to achieve hemodynamic goals.
- When **clinically significant edema** limits further crystalloid administration.

➢ Albumin Use:

- For patients with **low albumin concentration** who require large fluid volumes (e.g., paracentesis, cirrhosis).
- In **pulmonary edema** causing respiratory failure, with **low albumin**, when diuretics alone are ineffective.

Colloids in Fluid Resuscitation

Natural Colloids: Albumin

- **Status:** A safe but costly second-line option.
- **Indications:** Consider as an adjunct to crystalloids when a patient requires substantial crystalloid volume or is unresponsive. Recommended in specific settings like cirrhosis with SBP or hepatorenal syndrome.
- **Contraindication:** Avoid in severe traumatic brain injury (TBI), as the SAFE study showed increased mortality.

Synthetic Colloids: A Warning

AVOID

Hydroxyethyl Starch (HES)

Evidence: Associated with increased risk of Acute Kidney Injury (AKI), need for renal replacement therapy, and higher mortality (6S and CHEST trials).

Regulatory Action: The European Medicines Agency (EMA) suspended marketing authorizations for HES solutions in 2022 due to persistent risk of severe harm.

NOT RECOMMENDED

Gelatins & Dextrans

Evidence: Associated with increased risk of anaphylaxis, AKI, bleeding. The Surviving Sepsis Campaign advises against gelatin use.

Specific Considerations in Fluid Therapy

Core Principles of Modern Fluid Therapy

1. **Think in Phases:** Fluid therapy is a dynamic process. Match the fluid strategy to the clinical phase: *Maintenance* (stability), *Replacement* (deficit), or *Resuscitation* (crisis).

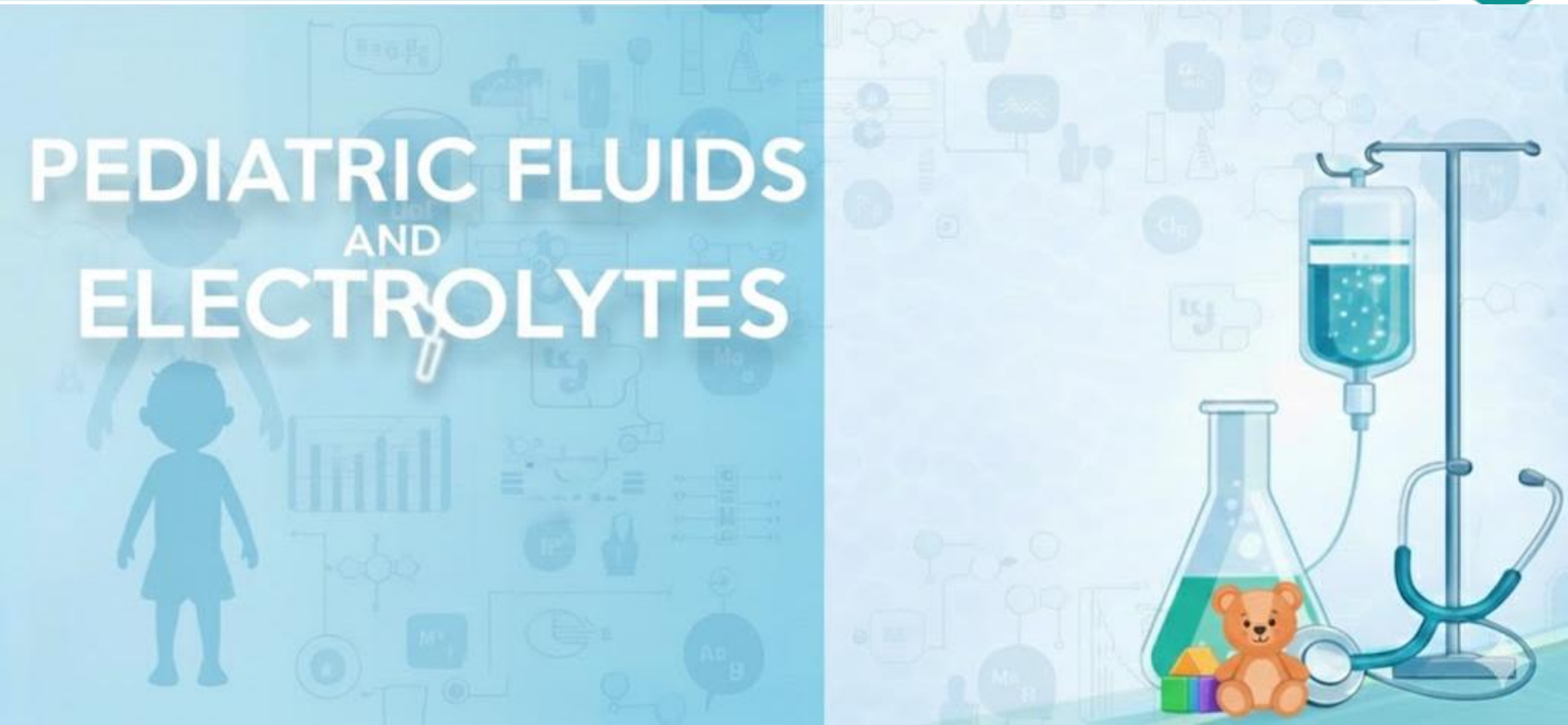
2. **Crystalloids are the Foundation:** For resuscitation, *crystalloids are the evidence-backed first-line choice.*

3. **Balanced Fluids First (Usually):** For most critically ill patients, especially those with sepsis or risk of AKI, *balanced crystalloids are the preferred initial fluid.* Normal saline remains the fluid of choice for specific indications like TBI.

4. **Avoid Synthetic Colloids:** *Hydroxyethyl starch (HES)* is associated with harm (AKI, mortality) and should be avoided.

5. **Monitor and De-escalate:** Fluid administration is a prescription. Continuously monitor the patient's response to *avoid the harms of fluid overload.* A restrictive strategy in the de-escalation phase (>96 hours) is associated with better outcomes.

Pediatric Fluid and Electrolyte Pharmacotherapy



Composition of Body Fluid

- The **fetus has the highest TBW content**, which gradually **decreases to about 75% for a full-term infant.**
- During the **first year of life**, the TBW will **decrease to about 60%** and **remain steady** at this percentage until puberty
- In general, the TBW is **60% in men and 50% in women**.
- This affects the TBW of men and women because the **fat content has a lower water content**, and **the muscle content has a higher water content**

Composition of Body Fluid

Term Infant
75% Total Body Water (TBW)

Adult
60% TBW

Higher Water Content: Infants have a TBW of ~75% of body weight, which decreases to the adult level of ~60% by one year of age.

Larger ECF Volume: The infant's ECF volume is larger than their ICF, making them more susceptible to fluid loss from this compartment.

Higher Metabolic Rate: The metabolic rate per unit of body weight declines with age. Infants have a higher turnover of water and electrolytes.

Increased Insensible Losses: A larger body surface area relative to weight leads to higher fluid loss.

These factors combine to create a narrow margin of safety. Dehydration can develop and progress rapidly in infants and young children.

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Body Fluid Compartments & Osmotic Regulation

I. Fluid Distribution in Adults

- Water is distributed between **two main compartments**: intracellular fluid (ICF) and extracellular fluid (ECF).
- In the **adult**, the **ICF is composed of two-thirds of the TBW**.
- The **ECF** is **one-third of the TBW**.
- The ECF is further divided into:
  - **Three-fourths (3/4) interstitial fluid**.
  - **One-fourth (1/4) plasma**.

Table 1. Approximate Electrolyte Composition of the ECF and ICF

	ECF (mEq/L)	ICF (mEq/L)
Na^+	135–145	10–20
K^+	3.5–5	120–150
Cl^-	95–105	0–3
HCO_3^-	22–30	10
Phosphate	2	110–120

EFC = extracellular fluid; ICF = intracellular fluid.
Information from reference 1.

Body Fluid Compartments & Osmotic Regulation

II. Developmental Changes (Pediatric vs. Adult)

- **The fetus's and newborn infant's ECF volume is larger than the ICF volume, but it decreases with age.**

- By **1 year of age,** the **ratio of ECF and ICF approaches the adult level**.
- This transition occurs due to:
  Postnatal diuresis at birth.
  Continued expansion of the ICF compartment **caused by cellular growth.**

Body Fluid Compartments & Osmotic Regulation

III. Chemical Composition (Cations & Anions)

- **In the ICF:**
  - Potassium (K+) is the predominant cation.
  - Phosphate (PO-) is the predominant anion.
- **In the ECF (Plasma and Interstitial Fluid):**
  - Sodium (Na+) is the dominant cation.
  - Chloride (Cl-) is the dominant anion.

Table 1.4 Major ions in ECF and ICF

	ECF	ICF
Major cation	Sodium	Potassium and magnesium
Major anion	Chloride and bicarbonate	Phosphate, sulfate and protein

IV. Regulation of Osmolality

- **Definition:** Osmolality represents the **number of osmoles (solutes)** per kilogram (Osm/kg).
- **Mechanism:** **Water** is the **primary factor** in maintaining osmotic balance.
- **Dynamics:** **Water moves freely across the cell membrane** between the ECF and ICF.

Maintenance Fluid and Electrolyte Requirements

I. Overview of Maintenance Needs

- Maintenance fluids and electrolytes are **essential to replace normal losses resulting from basal body metabolism.**

- **Infants** are **more susceptible to rapid dehydration** compared to **adolescents**, **necessitating higher maintenance requirements** on a **milliliter per kilogram basis**.

➢ **Clinical Example:** While an **adolescent may tolerate 12–18 hours of NPO** (nothing by mouth) **before surgery**, **an infant** typically **requires IV fluids within 4–6 hours of their last feeding to avoid dehydration.**

Maintenance Fluid and Electrolyte Requirements

II. Fluid Requirement Calculation Methods

There are several established methods for calculating requirements:

1. **Surface Area Method**.
2. **Basal Calorie Method**.
3. **Holliday-Segar Method:** This is **the most commonly used method** for calculating 24-hour maintenance fluid requirements in children.

Table 2. Holliday-Segar Method

Weight (kg)	24-Hour Maintenance Water Requirement for Infants, Children, and Adolescents	Maintenance Water Rate
≤ 10	100 mL/kg	4 mL/kg/hour
11–20	1,000 mL + 50 mL/kg for each kg > 10 kg	40 mL/hour + 2 mL/kg/hour × (wt – 10 kg)
> 20	1,500 mL + 20 mL/kg for each kg > 20 kg	60 mL/hour + 1 mL/kg/hour × (wt – 20 kg)

wt = weight.
Information from reference 7.

Maintenance Fluid and Electrolyte Requirements

III. Neonatal Considerations

- **Susceptibility: Premature neonates and newborns** are **highly susceptible to insensible losses** due to a **high body surface area relative to weight** **(5x more for premature neonates; 3x more for newborns).**

- **Weight-Based Intake:**
  - **Neonates < 1500 g:** Require **140–190 mL/kg/day.**
  - **Neonates > 1500 g:** Require **140–160 mL/kg/day.**

Once a neonate reaches **3 kg**, the **Holliday-Segar method** becomes the preferred calculation tool.

IV. Daily Electrolyte Requirements (Children)

- The standard 24-hour **maintenance requirements for children are**:
  - **Sodium (Na+):** 2–3 mEq/kg. **Potassium (K+):**1–3 mEq/kg. **Chloride (Cl-):** 2 mEq/kg
- ✓ **Contraindication: Potassium should not be administered to patients with acute/chronic renal failure or conditions involving potassium retention.**

Maintenance Fluid and Electrolyte Requirements

V. Intravenous Solution Selection

- **Hypotonic Fluids: Generally**, **offer an adequate balance of water and electrolytes** for pediatric maintenance.
- **Safety Threshold:** The **most hypotonic solution** that can be **safely used** is **0.45% Sodium Chloride** (Osmolality = 154 mOsm/L).
- **Risk of Extreme Hypotonicity:** Any solution with an osmolality **less than 154 mOsm/L** is **not recommended**.
  - Using solutions below this threshold causes **cell lysing**. This release of **intracellular potassium** can lead to **hyperkalemia**, **cardiac arrhythmias, and death**.

Assessing the Severity of Dehydration

Table 4. Signs and Symptoms Related to Severity of Dehydration

	Mild	Moderate	Severe
Infants	**1% to 5%[a]**	**6% to 9%[a]**	**> 10% (≥ 15% = shock)[a]**
Older Children	**1% to 3%[a]**	**4% to 6%[a]**	**> 6% (≥ 9% = shock)[a]**
Pulse	Normal, increased	Tachycardia	Rapid and weak pulse
Systolic blood pressure	Normal	Normal, low	Decreased, very low
Urine output	Decreased	Little or low UOP < 1 mL/kg/hour	Oliguria << 1 mL/kg/hour
Buccal mucosa	Slightly dry	Dry	Parched
Ant fontanelle	Normal	Sunken	Very sunken
Eyes	Normal	Sunken	Very sunken
Skin turgor/capillary refill	Normal	Delayed Cool and pale	Very delayed Cool and mottled
Skin (infants < 12 months of age)	Normal	Cool	Acrocyanosis
Tears	Normal	Decreased	No tears
Mental status	Normal	Normal to listless	Normal to lethargic or comatose
Thirst	Drinks normally; might refuse liquids	Thirsty; eager to drink	Drinks poorly; unable to drink

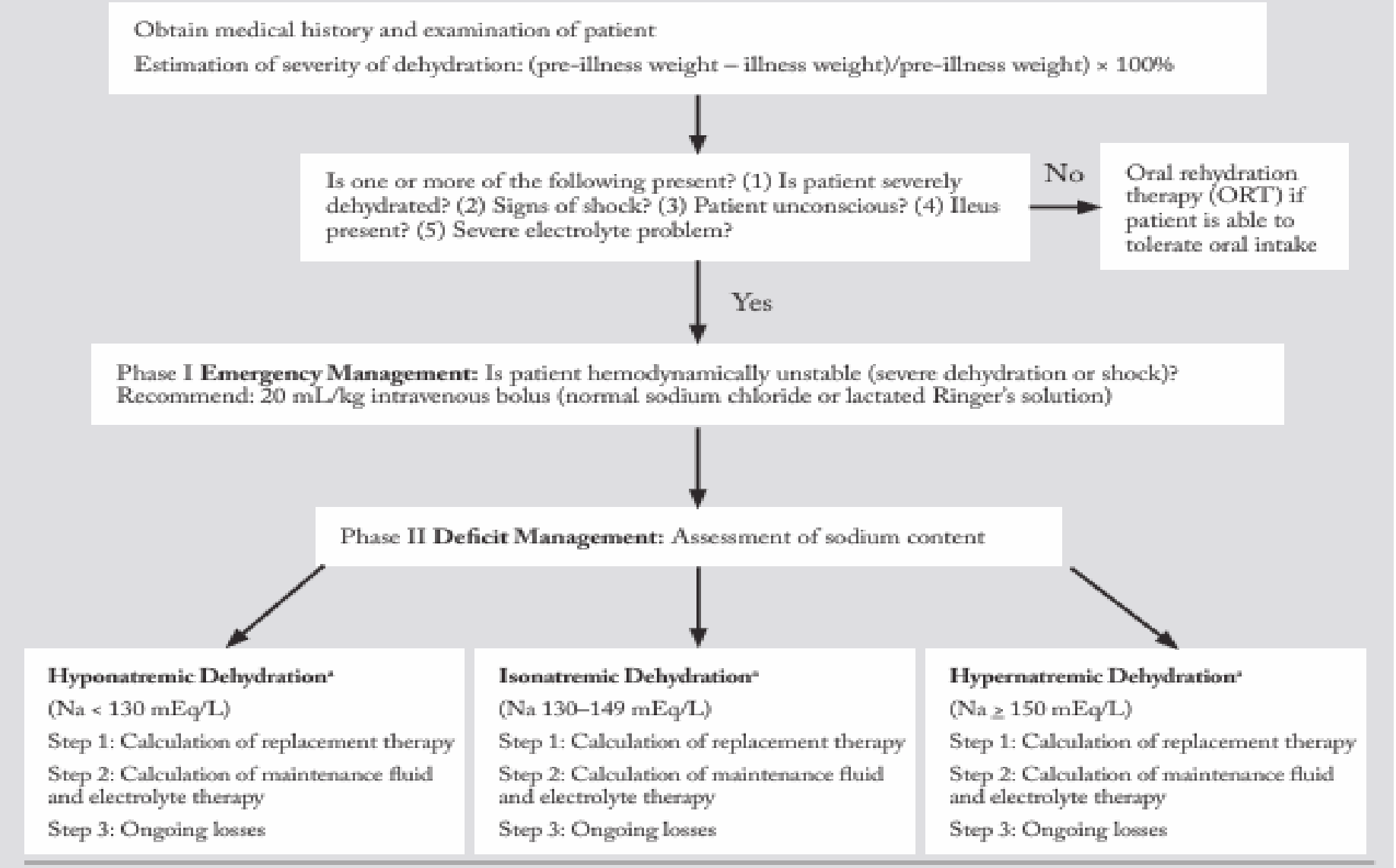
Assessing the Severity of Dehydration

The Spectrum of Dehydration

MILD	MODERATE	SEVERE
Infants: 1-5% weight loss	**Infants:** 6-9% weight loss	**Infants:** >10% weight loss (≥15% = shock)
Older Children: 1-3% weight loss	**Older Children:** 4-6% weight loss	**Older Children:** >6% weight loss (≥9% = shock)
Key Signs: Pulse normal/ increased, decreased urine output, slightly dry buccal mucosa, normal skin turgor, patient is thirsty but may refuse liquids.	**Key Signs:** Tachycardia, little urine output (<1 mL/kg/hr), dry buccal mucosa, sunken eyes/fontanelle, delayed capillary refill (2-3 seconds), cool extremities, listless, eager to drink.	**Key Signs:** Rapid/weak pulse, decreased/very low BP, oliguria (<<1 mL/kg/hr), parched mucosa, very sunken eyes, very delayed capillary refill (>3 sec), cool/mottled skin, lethargic/ comatose, unable to drink.

Severity is classified based on percentage of body weight loss [(Pre-illness weight – Illness weight) / Pre-illness weight] × 100%.

Assessing the Severity of Dehydration


Obtain medical history and examination of patient
Estimation of severity of dehydration: (pre-illness weight – illness weight)/pre-illness weight) × 100%
Is one or more of the following present? (1) Is patient severely dehydrated? (2) Signs of shock? (3) Patient unconscious? (4) Ileus present? (5) Severe electrolyte problem?
No
Oral rehydration therapy (ORT) if patient is able to tolerate oral intake
Yes
Phase I Emergency Management: Is patient hemodynamically unstable (severe dehydration or shock)? Recommend: 20 mL/kg intravenous bolus (normal sodium chloride or lactated Ringer's solution)
Phase II Deficit Management: Assessment of sodium content
Hyponatremic Dehydration[a]
(Na < 130 mEq/L)
Step 1: Calculation of replacement therapy
Step 2: Calculation of maintenance fluid and electrolyte therapy
Step 3: Ongoing losses
Isonatremic Dehydration[a]
(Na 130–149 mEq/L)
Step 1: Calculation of replacement therapy
Step 2: Calculation of maintenance fluid and electrolyte therapy
Step 3: Ongoing losses
Hypernatremic Dehydration[a]
(Na ≥ 150 mEq/L)
Step 1: Calculation of replacement therapy
Step 2: Calculation of maintenance fluid and electrolyte therapy
Step 3: Ongoing losses

Oral Rehydration Therapy (ORT)

- **Indications: Preferred treatment for children** with **mild and moderate dehydration** caused by **diarrhea**.

- **Acceptable Fluids:** Any commercially available rehydration fluid (e.g., Pedialyte).

- **Composition Guidelines:** Fluids should contain **2–3 g/dL glucose, 45–90 mEq/L sodium, 30 mEq/L base (acetate/citrate), and 20–25 mEq/L potassium.**

- **4-Hour Management Plan:**
  - ✓ **Mild:** Give **50 mL/kg plus replacement of continuing losses.**
  - ✓ **Moderate:** Give **100 mL/kg plus replacement of continuing losses**.

Continuing Losses: Give **10 mL/kg** for **every stool or emesis.**

IV Therapy: (Emergency & Deficit Management)

Phase I: Emergency Management

- ✓ **Goal:** Ensure **return of adequate intravascular volume** and avoid tissue damage.
- ✓ **Fluid Choice: 0.9% Sodium Chloride** (NS) or **Lactated Ringer's** (LR).
- ✓ **Standard Bolus: 20 mL/kg in the first 30 minutes**.
- ✓ **Unstable Patients: May require up to 40 mL/kg.**

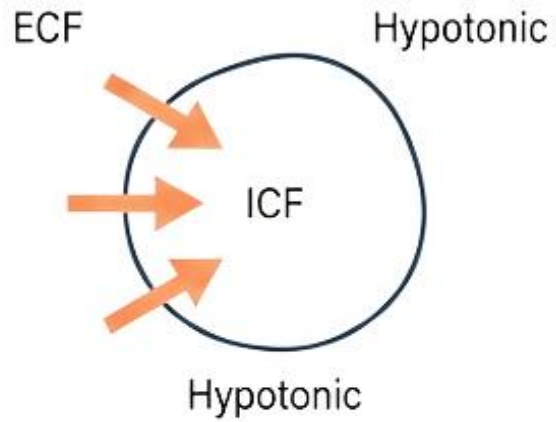
Phase II: Deficit Management

✓ **Combines deficit replacement, maintenance therapy, and ongoing losses.**

✓ **Fluid selection depends on serum sodium levels (Hyponatremia, Isonatremia, or Hypernatremia).**

IV Therapy: (Emergency & Deficit Management)

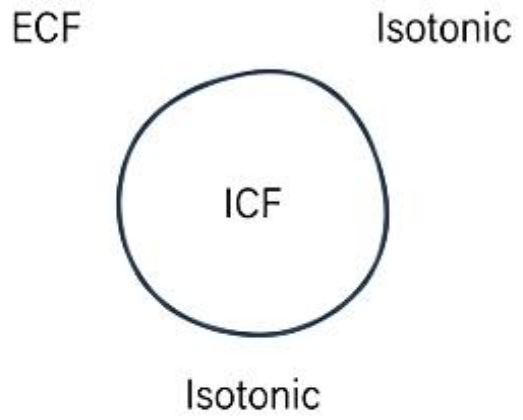
Hyponatremic Dehydration (Na < 130 mEq/L)



Pathophysiology: ECF is hypotonic. Water shifts from the ECF into the ICF to maintain osmotic equilibrium.

Clinical Consequence: Worsens intravascular volume depletion (shock) and can cause cerebral edema.

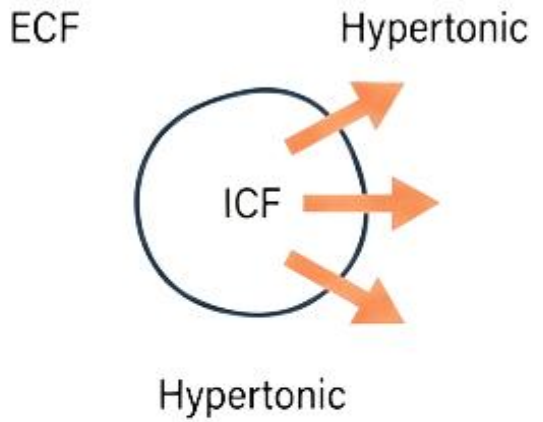
Isonatremic Dehydration (Na 130-149 mEq/L)



Pathophysiology: Water and sodium loss is proportional. No significant osmotic shift between ECF and ICF.

Clinical Consequence: Most common type; volume loss is primarily from the ECF.

Hypernatremic Dehydration (Na > 150 mEq/L)



Pathophysiology: ECF is hypertonic. Water shifts from the ICF to the ECF.

Clinical Consequence: Preserves intravascular volume (signs of shock appear later), but causes brain cell shrinkage and risk of intracranial hemorrhage.

IV Therapy: (Emergency & Deficit Management)

Phase I: Emergency Management

When the patient is hemodynamically unstable, the immediate goal is to restore intravascular volume.

IN SHOCK? START HERE.

- **WHAT**: Isotonic Fluid
  - 0.9% Sodium Chloride (Normal Saline)
  - Lactated Ringer's Solution
- **HOW MUCH**: 20 mL/kg
- **HOW FAST**: Administer as a bolus over the first 30 minutes.
- **THEN WHAT**: Reassess the patient. If they remain unstable, the bolus may be repeated. Persistent hypovolemia may require a 40 mL/kg bolus.

IV Therapy: (Emergency & Deficit Management)

Phase II: The Strategic Plan for Rehydration

Deficit

Definition: The fluid and electrolytes already lost before presentation.

Calculation: Fluid Deficit (L) = % dehydration × pre-illness weight (kg).

Sodium deficit = Fluid deficit (L) × 0.6 (L/kg) × normal serum sodium (140 mEq/L)

Maintenance

Definition: The normal daily fluid and electrolyte requirements to account for basal metabolism.

- < 10 kg → 100 mL/kg
- 11-20 kg → 1000 mL + 50 mL/kg for each kg > 10
- > 20 kg → 1500 mL + 20 mL/kg for each kg > 20

Ongoing Losses

Definition: Abnormal losses that continue after therapy has begun (e.g., from continued diarrhea, emesis, NG tube suction).

Action: These must be measured or estimated and replaced.

Hyponatremia - Clinical Manifestations

- **Definition:** Serum sodium concentration **< 130 mEq/L.**

- **Common Causes:** Acute **gastroenteritis** and **loop diuretics** (e.g., furosemide).

- **Neurologic Symptoms (Brain Swelling):**
  - Lethargy, confusion, agitation, and headache.
  - **Sodium < 125 mEq/L:** Nausea and malaise.
  - **Sodium < 120 mEq/L:** Seizures (often refractory to antiepileptics).

Correction of Hyponatremia

- **The Safety Rule: Avoid correcting serum sodium by more than 12 mEq/L in 24 hrs.**
- **Initial Aggressive Phase:** Rise in sodium should not exceed **2 mEq/L per hour** during the **first 3-4 hours.**
- **Symptomatic Management (Seizures):**
  - Use **3% Hypertonic Saline** to increase sodium rapidly.
  - **Dose: 4 mL/kg of 3% Saline** increases serum sodium by **about 1 mEq/L**

- **Risk of Rapid correction** causes **Central Pontine Myelinolysis** (irreversible neurologic injury).
- **Classic Features of CPM:**
  - Mutism and Dysarthria.
  - Spastic Quadriplegia.
  - Pseudobulbar palsy and Ataxia.

Isonatremic (Isotonic) Dehydration

- **Isonatremic dehydration** is defined as a **serum sodium concentration between 130 mEq/L and 149 mEq/L**. Isonatremic dehydration **occurs when the degree of water** and **sodium losses** is **equal** in both **ICF and ECF**.

- **In emergency phase I** for a **hemodynamically unstable patient** an **isotonic fluid (0.9% sodium chloride or lactated Ringer's solution)** is **given as a bolus of 20 mL/kg over 30 minutes** and repeated if necessary.

- **phase II, requires a calculation of both fluid and sodium deficit to determine the type and amount, of fluids needed.**

Isonatremia: Phase II Deficit Schedule

❖ **The 24-Hour Protocol:**

- **First 8 Hours:** Give **1/2 of remaining deficit + 1/3 of daily maintenance.**
- **Next 16 Hours:** Give **1/2 of remaining deficit + 2/3 of daily maintenance.**

❖ **Typical Fluid: 5% Dextrose in 0.2% to 0.45% NaCl + 20 mEq/L KCl.**

❖ **Metabolic Acidosis:** Use **Potassium Acetate** instead of **KCl** ??
(Acetate converts to bicarbonate in the liver).

Hypernatremic Dehydration: Clinical Overview

- **Definition**: A **serum sodium concentration** of **150 mEq/L or greater**.

- **Pathophysiology**: **Movement of water from brain cells to the ECF.**

- **Neurologic Manifestations**:
  - **Brain cell shrinkage** (decrease in brain volume).
  - **Tearing of blood vessels within the brain** (hemorrhages).
  - **Cerebral contraction**.

- **Primary Objective**: **Correct hypernatremia** while strictly **preventing cerebral edema**.

Correction of Hypernatremia: Phase I & Safety Limits

➢ **Phase I (Intravascular Restoration):**

- **First Step**: Administer **0.9% sodium chloride 20 mL/kg** within **20–30 minutes.**
- **Caution**: **Lactated Ringer's solution is avoided** because **it is more hypotonic (Na = 130 mEq/L)**, which may **lead to rapid sodium correction**.

➢ **Correction Velocity Rules:**

- The free water deficit **must not be replaced too rapidly.**
- **Maximum Correction**: **Decrease serum sodium** by **no more than 12 mEq/L in 24 hours.**
- **Risk**: Rapid lowering of extracellular osmolality causes water **to move into brain cells**, leading to **cerebral edema**.

Phase II: Correction Timeline and Fluid Selection

❖ **Replacement Fluids**:

- **5% dextrose** in 0.45% sodium chloride. **D5W 0.45%NS**
- **OR** 5% dextrose in 0.2% sodium chloride.
- **Additives**: Include **20 mEq/L KCl** (unless contraindicated).

Required Correction Time Based on Initial Sodium:

Initial Sodium Concentration	Correction Time Required
150–157 mEq/L	24 Hours
158–170 mEq/L	48 Hours
171–183 mEq/L	72 Hours
184–196 mEq/L	84 Hours

Phase II: Correction Timeline and Fluid Selection

The High-Stakes Case: Managing Hypernatremic Dehydration

⚠ **GO SLOW:** Rapidly lowering serum osmolality will cause water to shift into brain cells, leading to cerebral edema, seizures, and permanent neurologic injury.

The Goal: Slowly correct the volume deficit and serum sodium. Do not lower serum sodium by more than 12 mEq/L over 24 hours.

The Plan: Correction should occur over 48-72 hours.

1. **Step 1 (Emergency):** If in shock, restore intravascular volume with 0.9% NaCl boluses. Avoid the more hypotonic Lactated Ringer's.
2. **Step 2 (Calculate Deficits):**
   - Calculate the Total Fluid Deficit (TFD).
   - Calculate the Free Water Deficit (FWD) separately:
   FWD (mL) = 4 mL × (Actual Na – Desired Na) × Body Wt (kg).
3. **Step 3 (Replace Slowly):** The calculated fluid deficit (TFD + Maintenance) is replaced evenly over 48-72 hours.
4. **Step 4 (Monitor):** Check serum sodium every 4-6 hours initially to ensure a slow, gradual decline.

Phase II: Correction Timeline and Fluid Selection

Table 7. Causes of Hypernatremia and Hyponatremia

Hypernatremia	Hyponatremia
Improperly mixed formula	Hyperglycemia
Excess sodium bicarbonate	Mannitol
Ingestion of seawater or sodium chloride	Gastrointestinal (emesis, diarrhea)
Intentional salt poisoning	Skin (sweating or burns)
Intravenous hypertonic sodium chloride	Third space losses
Hyperaldosteronism	Urinary tract obstruction and/or urinary tract infection
Nephrogenic diabetes	Thiazide or loop diuretics
Central diabetes insipidus	Cerebral salt wasting
Increased sensible losses	Diluted formula
Diarrhea	Syndrome of inappropriate antidiuretic hormone
Emesis/nasogastric suction	Hypothyroidism
Burns	Water intoxication
Excessive sweating	Nephrotic syndrome
Osmotic diuretics (e.g., mannitol)	Congestive heart failure

Information modified from reference 2.

Phase II: Correction Timeline and Fluid Selection

Table 6. Treatment Summary for Dehydration

	Hyponatremic Dehydration (< 130 mEq/L)	Isonatremic Dehydration (130–149 mEq/L)	Hypernatremic Dehydration (≥ 150 mEq/L)
Step 1: Calculation of the replacement therapy			
Fluid deficit	Fluid deficit (L) = % dehydration × weight (kg)	Fluid deficit (L) = % dehydration × weight (kg)	TFD = % dehydration × weight (kg) SFD = TFD – FWD
Free water deficit[a]	Not applicable	Not applicable	FWD = 4 mL × (actual sodium – desired sodium mEq/L) × body weight (kg)
Sodium deficit[b]	Fluid deficit (L) × 0.6 (L/kg) × normal serum sodium concentration (140 mEq/L)	Fluid deficit (L) × 0.6 (L/kg) × normal serum sodium concentration (135 mEq/L)	SFD (L) × 0.6 (L/kg) × normal serum sodium concentration (140 mEq/L)
Excess sodium deficit	(Desired serum sodium [135 mEq/L] – actual serum sodium) × 0.6 (L/kg) × body weight (kg)	Not applicable	Not applicable
Potassium deficit[c]	Fluid deficit (L) × 0.4 (L/kg) × 120 mEq/L	Fluid deficit (L) × 0.4 (L/kg) × 120 mEq/L	SFD (L) × 0.4 (L/kg) × 120 mEq/L
Step 2: Calculation of maintenance fluid and electrolyte therapy			
Holliday-Segar method (Table 2)			
Step 3: Ongoing losses: Refer to Table 5 for the electrolyte composition of various body fluids.			

FWD = Free water deficit; SFD = Solute fluid deficit; TFD = Total fluid deficit.

[a]Pure water deficit is part of the TFD.
[b]0.6 L/kg means sodium distribution factor as fraction of body weight.
[c]0.4 L/kg means potassium distribution factor as fraction of body weight; 120 mEq/L is the normal value of intracellular potassium concentration.
Information from references 1,2, 9.

Case Study 1

Patient Presentation: 12-month-old male. Pre-illness weight: 8 kg. Current weight: 7.5 kg. Serum Na: 129 mEq/L.

1. **Assessment:**
   - Weight Loss: (8 – 7.5) / 8 = 6% dehydration (Moderate).
   - Type: Hyponatremic.
2. **24-Hour Requirements Calculation:**
   - **Water**: Deficit (480 mL) + Maintenance (800 mL) = **1280 mL Total**
   - **Sodium**: Na Deficit (40 mEq) + Excess Na Deficit (29 mEq) + Maintenance (24 mEq) = **93 mEq Total**
   - **Potassium**: Deficit (23 mEq) + Maintenance (16 mEq) = **39 mEq Total**
3. **The Plan:**

First 8 Hours:
Fluid: 507 mL (Rate: ~63 mL/hr)
Sodium: 42.5 mEq

Next 16 Hours:
Fluid: 773 mL (Rate: ~48 mL/hr)
Sodium: 50.5 mEq

4. **Fluid Selection:**

5% Dextrose + 0.45% NaCl + 20-30 mEq/L KCl meets the calculated needs.

Case Study 2

Patient Presentation: 12-month-old male. Pre-illness weight: 8 kg. Current weight: 7.2 kg. Serum Na: 151 mEq/L. Hypotensive, delayed capillary refill.

1. **Assessment & Emergency Phase:**
   - Weight Loss: (8 – 7.2) / 8 = 10% dehydration (Severe).
   - Type: Hypernatremic.
   - **Phase I Action:** Give 160 mL (20 mL/kg) bolus of **0.9% NaCl.**

2. **48-Hour Requirements Calculation (Slower Correction):**
   - **Water:** Free Water Deficit (192 mL) + Solute Deficit (608 mL) + Maintenance (800 mL/day x 2 days) = **2400 mL Total over 48h.**
   - **Sodium:** Na Deficit (50 mEq) + Maintenance (24 mEq/day x 2 days) = **98 mEq Total over 48h.**

3. **The Plan (Over 48 Hours):**
   - **Infusion Rate:** 2400 mL / 48 hrs = **~50 mL/hr.**

4. **Fluid Selection:**
   - 5% Dextrose + 0.225% NaCl + 20 mEq/L KCl provides an appropriate low-sodium fluid for gradual correction.

Case Study 2

Common IV Fluids

0.9% NaCl (Normal Saline)
- Sodium: 154 mEq/L
- Osmolality: 308 mOsm/L
- Use: Isotonic fluid for emergency volume expansion.

Lactated Ringer's (LR)
- Sodium: 130 mEq/L
- Osmolality: 273 mOsm/L
- Use: Isotonic fluid for emergency volume expansion (avoid in hypernatremia).

0.45% NaCl (Half Normal)
- Sodium: 77 mEq/L
- Osmolality: 154 mOsm/L
- Use: Hypotonic fluid for deficit/maintenance therapy.

5% Dextrose + 0.225% NaCl (D5 ¼ NS)
- Sodium: 38.5 mEq/L
- Osmolality: 329 mOsm/L
- Use: Common maintenance fluid, especially for hypernatremic correction.

Essential Monitoring

Clinical Signs: Re-evaluate skin turgor, capillary refill, mental status, and vital signs.

Body Weight: The most objective measure of fluid status.

Urine Output: Target > 1 mL/kg/hour. Oliguria is a key warning sign.

Serum Electrolytes: Frequent reassessment (q4-6h initially in dysnatremia) is critical to guide and adjust therapy.

Review

Common IV Fluids

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Review

The 4 Core Principles of Pediatric Rehydration

1.

Assess Accurately

Your entire plan depends on correctly classifying the degree (% weight loss) and type (serum sodium) of dehydration at the outset.

2.

Restore Volume First

In a hemodynamically unstable child, shock is the immediate threat.

Act fast with 20 mL/kg isotonic boluses before proceeding to calculated deficit replacement.

3.

Correct Slowly & Strategically

Base your deficit replacement strategy on the serum sodium.

Remember the primary rule for hypernatremia: GO SLOW (correct over 48-72h) to prevent cerebral edema.

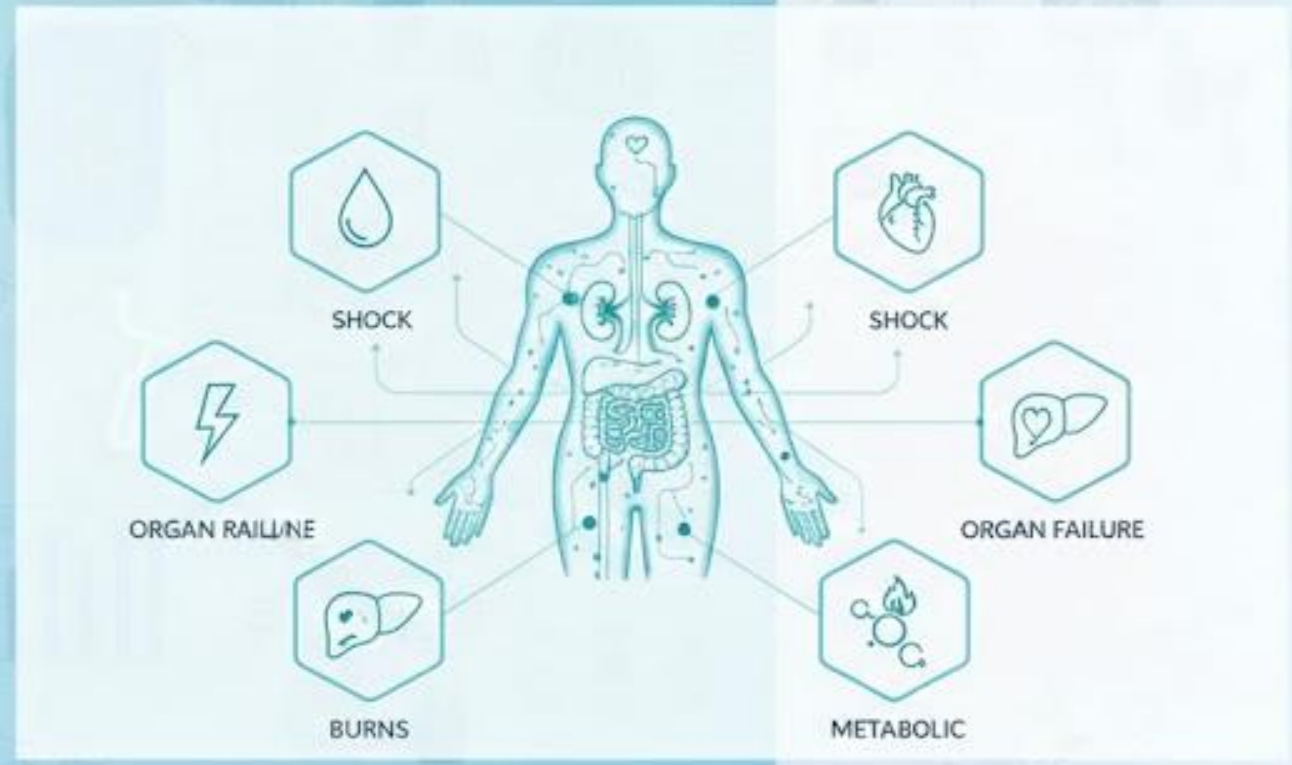
4.

Monitor & Adjust

Fluid management is not "set it and forget it." The initial plan is a starting point.

Continuously re-assess the patient, their weight, urine output, and labs to dynamically adjust your therapy.

Disease-Specific Fluid Management



1- Operative fluid therapy

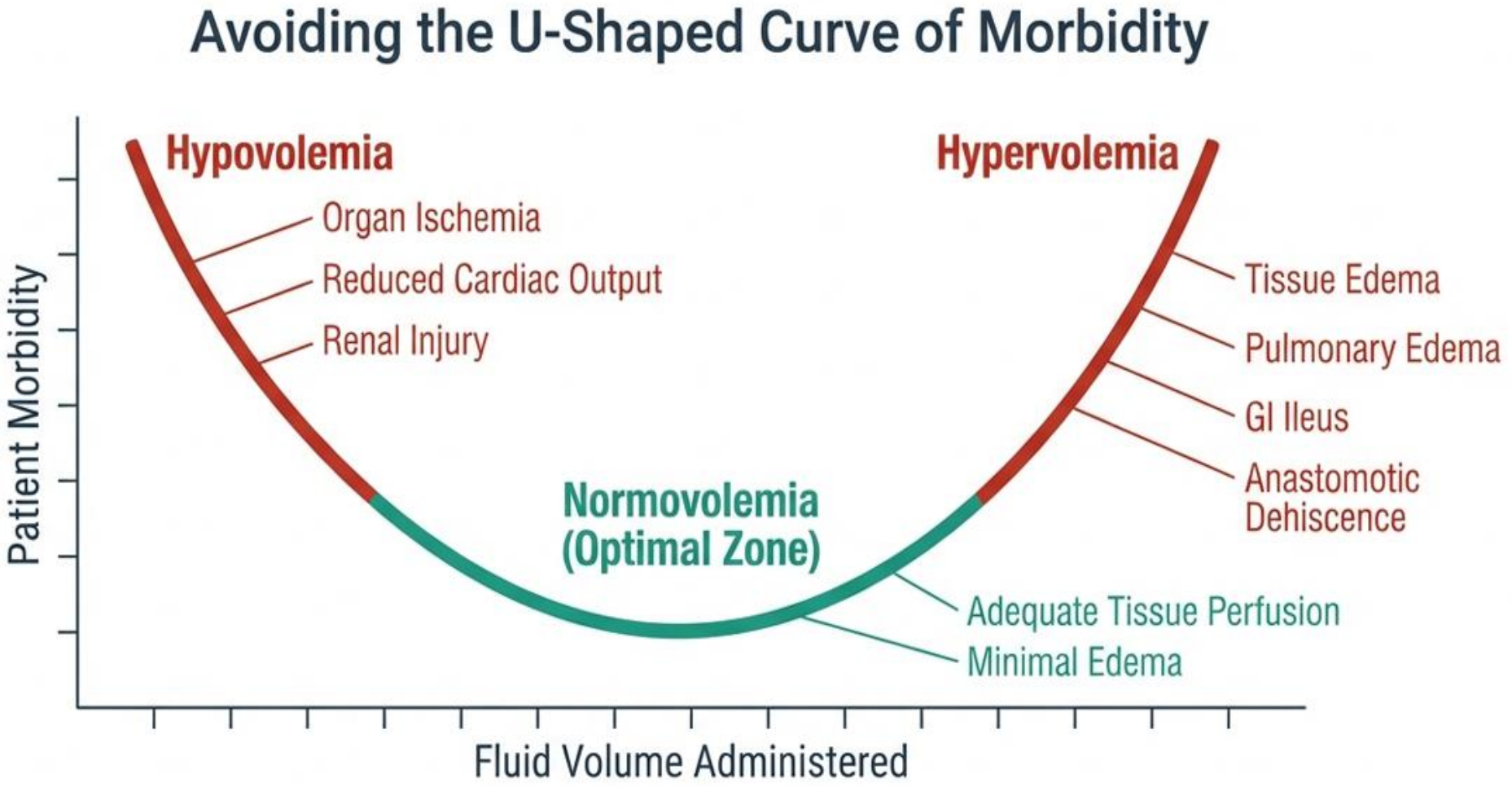
I. Core Objective: The Pursuit of Euvolemia

- The primary goal of perioperative fluid therapy is to maintain **normovolemia (euvolemia)** to ensure **adequate tissue perfusion.**

- **Hypovolemia** leads to **reduced cardiac output** and **organ ischemia**, potentially progressing **to shock** or **multiorgan failure.**

- **Hypervolemia** is **equally dangerous**, causing **tissue edema** that **impairs oxygen exchange**, **compromises wound healing**, and **increases the risk of postoperative respiratory failure** and **gastrointestinal ileus**.

1- Operative fluid therapy



Normovolemia should be maintained throughout the perioperative period. Both hypovolemia and hypervolemia are associated with significant postoperative morbidity.

1- Operative fluid therapy

I. Preoperative Phase: Minimizing Deficits

Preoperative management focuses on avoiding dehydration while respecting fasting protocols.

- **Fasting Guidelines:** While **10 hours of fasting does not significantly deplete intravascular volume**, clear oral liquids are encouraged up to **two hours before surgery** to **prevent dehydration.**

- **Volume Losses:** Pharmacists should note that **mechanical bowel preparations** can cause significant gastrointestinal fluid loss, potentially reducing preoperative volume status.

1- postoperative fluid therapy

I. The Physiologic Stress Response to Surgery

Surgery triggers a "fight or flight" biochemical cascade designed for survival, but it can lead to significant fluid shifts and organ dysfunction.

Hormonal & Chemical Mediators

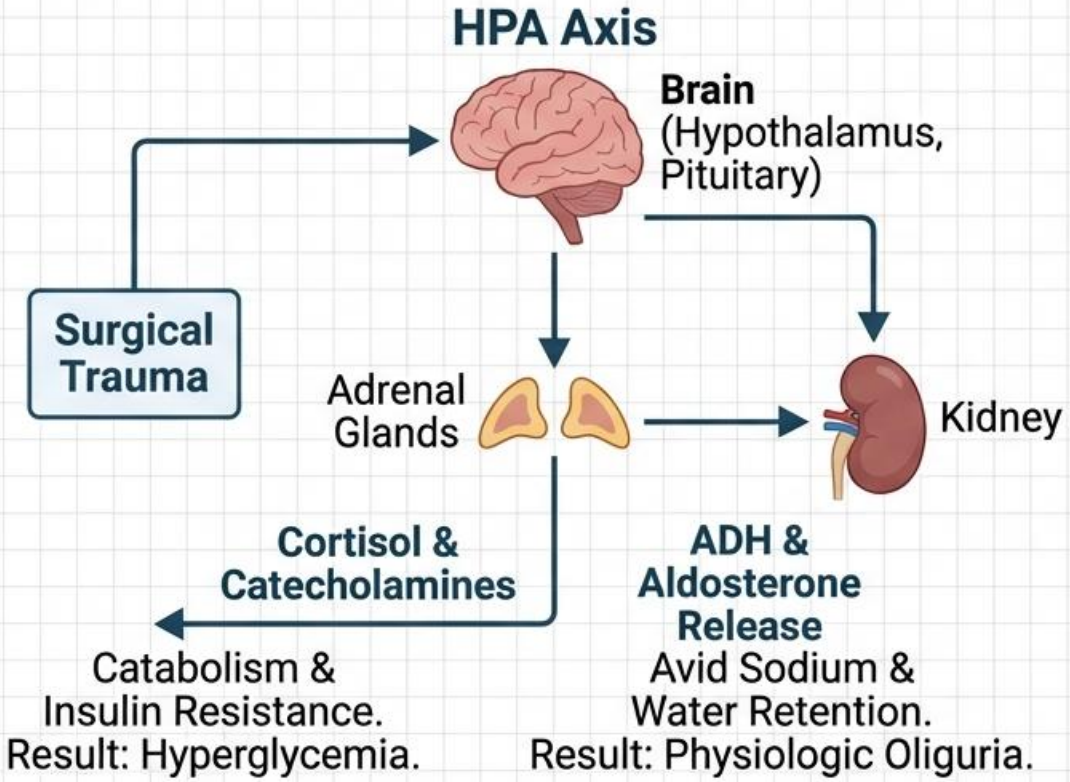
- **Vasopressin (ADH):** Causes water retention to expand vascular volume.
- **Aldosterone:** Increases sodium and water retention; may lead to **hypokalemia**.
- **Cortisol & Catecholamines:** Drive hyperglycemia and tachycardia.
- **Cytokines:** Induce local inflammation and systemic capillary leak ("third-spacing").

Clinical Note: Tachycardia and oliguria in a postoperative patient may be a manifestation of the **stress response** rather than simple hypovolemia. Over-resuscitation in these cases can lead to volume overload.

1- postoperative fluid therapy

Postoperative Physiology: The Stress Response

Distinguishing Physiologic Response from Hypovolemia



Clinical Implication:
Post-op oliguria (<0.5 mL/kg/hr) is often **hormonal**, not due to dehydration. Do not blindly treat stable oliguria with fluid boluses.

1- postoperative fluid therapy

II. Postoperative Fluid Losses

Fluid loss varies by procedure and the intensity of the inflammatory response.

- **Bleeding:** Signs (tachycardia, hypotension) often only appear after **>15% blood volume loss**.
- **Drainage:** Significant losses from nasogastric (NG) tubes, chest tubes, or abdominal drains must be replaced to prevent electrolyte derangement.
- **Third-Spacing:** The extravasation of protein-rich serum into interstitial spaces. This is most intense in the first **72 hours** post-op.
- **Insensible Losses:** Evaporative loss from open abdominal/thoracic cavities or large burn wounds.

1- postoperative fluid therapy

III. Fluid Resuscitation Strategy

The goal is to **restore organ perfusion**, not just match a numerical volume deficit.

1. Choice of Fluid

Fluid Type	Best Use Case	Precautions
❑ **Isotonic Crystalloids (NS, LR)**	First-line for simple replacement.	Large volume NS can cause **hyperchloremic acidosis**.
❑ **0.9% Normal Saline**	Preferred for brain injury or metabolic alkalosis.	Avoid in hyperkalemia or severe renal failure.
❑ **Lactated Ringer (LR)**	Ideal for most surgical resuscitations.	Contains K^+; avoid in hyperkalemia.
❑ **Albumin (Colloid)**	Liver failure or severe malnutrition.	No proven mortality benefit over crystalloids.
❑ **Blood Products**	Active hemorrhage or symptomatic anemia.	Aim for Hb **7–8 g/dL** (8–10 g/dL in CAD).

1- postoperative fluid therapy

III. Fluid Resuscitation Strategy

The goal is to **restore organ perfusion**, not just match a numerical volume deficit.

2. Volume and Rate

- **Fluid Challenge:** Typically **500–1000 mL** boluses of crystalloid.
- **Ongoing Losses:** Replace drain output 1:1 if losses are high (e.g., >50 mL/hr).
- **Refractory Cases:** If the patient is unresponsive to boluses, reconsider the diagnosis (e.g., occult bleeding, MI, or sepsis) rather than continuing aggressive fluids.

1- postoperative fluid therapy

IV. Endpoints of Resuscitation:

- Success is defined by restored oxygen delivery to tissues.
- **Clinical Markers:** Normalization of heart rate, BP, mental status, and **Urine Output (>0.5 mL/kg/hr)**.

- **Serum Markers: Lactic Acid:** Trend should be downward.
  - **Base Deficit:** Should normalize as perfusion improves.
  - **SvO2:** Measures oxygen extraction; lower values suggest under-perfusion.

- **Dynamic Assessment: Passive Leg Raise** (equivalent to a 300 mL bolus) to check for fluid responsiveness.

1- postoperative fluid therapy

V. Maintenance Fluid Therapy

Provided when the patient cannot tolerate oral/enteral intake.

- ✓ **Daily Requirement:** Approximately **30 mL/kg/day** (1–1.5 mL/kg/hr).
- ✓ **Selection:** Isotonic or hypotonic saline (0.45% NS).
- ✓ **Dextrose:** Often excluded post-op to avoid hyperglycemia unless the patient is at risk for hypoglycemia.
- ✓ **Mobilization:** As inflammation subsides, "third-space" fluid returns to the vascular space (auto-diuresis); maintenance rates should be reduced accordingly.

2- Management of Severe Hypovolemia & Shock in Adults

1. Clinical Foundation

- **Definition:** Severe hypovolemia occurs when loss of blood or ECF results in decreased peripheral perfusion.

- **Hypovolemic Shock:** Present when severe hypovolemia results in **organ dysfunction** due to inadequate tissue perfusion.

- **Key Principle:** Identify and treat the underlying etiology (GI loss, Renal, Hemorrhage, or Third-spacing) concurrently with fluid therapy.

2- Shock Syndromes & Fluid Strategies

2. Choice of Replacement Fluid

- **Hemorrhagic Shock:**
  - **Mainstay:** Blood products (PRBCs).
  - **Strategy:** Use Isotonic Crystalloids (0.9% NS) only as a bridge while waiting for blood delivery.
- **Non-Hemorrhagic Shock:**
  - **First-line:** Isotonic Crystalloids (0.9% Saline or Buffered solutions like L R).
  - **Buffered Crystalloids (LR/Plasma-Lyte):** Preferred during large-volume resuscitation ($\ge$ 2 L) to avoid **Hyperchloremic Metabolic Acidosis**.
  - **Second-line:** Colloids (Albumin) may be considered if there is a limited response to crystalloids or in specific cases like cirrhosis.
  - **Contraindicated: Hyperoncotic Starch (HES)** must be avoided due to increased risks of **Acute Kidney Injury (AKI)** and mortality.

2- Shock Syndromes & Fluid Strategies

3. Monitoring & Hemodynamic Response

- **Clinical Indicators:** Monitor BP, Jugular Venous Pressure (JVP), mental status, and Urine Output.
- **Laboratory Markers:** * **Lactate Levels:** Serial measurements within the first 6 hours to assess perfusion.
  - **Urine Sodium:** If $< 15 \text{ mEq/L}$, the kidneys are sensing persistent volume depletion.
- **Over-resuscitation:** Be vigilant for pulmonary edema and "fluid creep." Peripheral edema alone is not always a marker of fluid overload (often due to dilutional hypoalbuminemia).

2- Shock Syndromes & Fluid Strategies

4. Refractory Shock Management

- **Vasoactive Agents: Norepinephrine** is added only when shock is refractory to aggressive fluid administration to maintain MAP. It does *not* correct the primary volume deficit.
- **Additional Tools:** Consider Point-of-Care Ultrasound (POCUS) to assess the Inferior Vena Cava (IVC) collapse or dynamic monitoring (Passive Leg Raising).

Parameter	Guideline Recommendation
Initial Fluid	0.9% Saline or Balanced Crystalloids (LR).
Volume Goal	Individualized based on deficit and ongoing losses.
Hemorrhage	Immediate transition to Blood Products.
Avoid	HES / Hydroxyethyl Starch.
Success Marker	Normalizing Lactate, MAP >65, and UOP >0.5 mL/kg/hr.

3- Heart Failure Fluid Management

Patients with heart failure (HF) are highly susceptible to **fluid overload** due to reduced cardiac output and secondary renal retention. Effective management focuses on precision and avoiding excess volume.

Core Management Strategies

- ✓ **Restrict Unnecessary Fluids**: Avoid generous fluid administration in euvolemic or mildly hypovolemic patients; fluid restriction is often required.
- ✓ **Prioritize Diuresis in Acute Decompensation**: In "wet" patients, diuresis is the mainstay; fluids can worsen pulmonary edema even if the patient is hypotensive (cardiogenic hypotension).
- ✓ **Limit IV Maintenance**: Continuous IV fluids should be avoided or kept at very low rates (e.g., 20–50 mL/h KVO); use saline locks when possible.
- ✓ **Adhere to Chronic Limits**: Maintain established fluid and sodium restrictions (typically <2 L/day) unless an acute volume deficit arises.

3- Heart Failure Fluid Management

Handling Hypovolemia and Advanced HF

- ✓ **Careful Rehydration**: If hypovolemia occurs (e.g., from over-diuresis), administer small aliquots (**100–250 mL**) while monitoring closely for lung crackles.
- ✓ **Colloid Consideration**: 5% Albumin may be preferred for hypotensive HF patients needing volume, as it stays intravascular and provides effect with less volume.
- ✓ **Advanced Support**: Critical cases may require inotropic support, pressors, and hemodynamic monitoring (e.g., Swan-Ganz catheters) to optimize filling pressures.

Monitoring and Special Procedures

- ✓ **Rigorous Monitoring**: Track daily weights, intake/output (I/O), electrolytes, and renal function to detect prerenal azotemia caused by aggressive diuresis.
- ✓ **Transfusion Precautions**: Give diuretics (e.g., furosemide) between units of blood during multiple transfusions to prevent volume overload

4- Renal Failure Fluid Management

Fluid management in renal failure requires a precise approach based on the specific type of injury and the patient's current phase of illness.

Acute Kidney Injury (AKI)

- ✓ **Pre-renal AKI**: Give isotonic crystalloids to restore renal perfusion; success is marked by increased urine output and stabilized creatinine.
- ✓ **Intrinsic or Post-renal AKI**: Often involves oliguria and volume overload, necessitating strict fluid restriction.
- ✓ **Hypotension with Overload**: In patients with "third-spacing," utilize vasopressors or cautious colloids rather than continuous fluid administration to avoid worsening outcomes.
- ✓ **Oliguric/Anuric Patients**: Avoid fluid overloading; these patients may require diuretics or dialysis.

4- Renal Failure Fluid Management

Chronic Kidney Disease (CKD)

- ✓ **General Restriction**: CKD patients cannot excrete excess water or electrolytes efficiently; avoid continuous IV fluids unless clearly indicated.
- ✓ **Stage 5/ESRD**: Often requires strict fluid restriction (e.g., 1 L/day) to prevent pulmonary edema.
- ✓ **Dialysis-Dependent Patients**: Volume issues are primarily managed by adjusting dialysis; fluids for depletion (e.g., GI loss) must be given with the anticipation of later removal via dialysis.
- ✓ **Early Stage CKD**: Maintenance fluids can be administered modestly if the patient has normal output.

4- Renal Failure Fluid Management

Electrolyte and Specialized Phases

- ✓ **Potassium Safety**: Typically avoid potassium-containing fluids like Lactated Ringer's (LR); use Normal Saline (NS) or D5W instead, especially if hyperkalemic.
- ✓ **Metabolic Acidosis**: Bicarbonate or the lactate in LR can act as buffers, though severe cases require IV bicarbonate or dialysis.
- ✓ **ATN Recovery (Polyuric Phase)**: During this phase, patients may lose liters of dilute urine; matching fluid and electrolyte replacement (K+, Mg++) is vital to avoid dehydration.

Monitoring & Intervention

- ✓ **Clinical Tracking**: Perform daily weights and monitor blood pressure, edema, and lung sounds.
- ✓ **Nephrology Involvement**: Use diuretics for volume overload if kidneys are responsive; otherwise, involve nephrology early for ultrafiltration.

5- Liver Cirrhosis & Ascites Fluid Management

In cirrhosis, patients exist in a paradoxical state: they have total body fluid retention (edema/ascites) but low effective arterial volume due to systemic vasodilation.

Core Principles of Management

- **Primary Treatment**: First-line management for ascites is fluid/salt restriction and oral diuretics (spironolactone/furosemide), not IV fluids.

- **Strict Restrictions**: Patients typically require a low-sodium diet (<2 g/day) and fluid restriction (1–1.5 L/day) if serum sodium is <130 mEq/L.

- **Inpatient Precautions**: For NPO patients, use low IV volumes; avoid hypotonic fluids (like D5W) as they worsen hyponatremia and ascites.

5- Liver Cirrhosis & Ascites Fluid Management

Critical Albumin Indications

1. **Large-Volume Paracentesis**: If >5 L is removed, administer **8 grams of 25% albumin per liter** removed to prevent circulatory collapse.
2. **Spontaneous Bacterial Peritonitis (SBP)**: Administer albumin at **1.5 g/kg** on diagnosis and **1 g/kg** on day 3 to reduce mortality and renal failure risks.
3. **Hepatorenal Syndrome (HRS)**: Use high-dose IV albumin (e.g., 25 g daily or BID) with vasoconstrictors to improve renal perfusion; avoid saline boluses.

5- Liver Cirrhosis & Ascites Fluid Management

Emergency Scenarios & Hemodynamics

- **Variceal Bleeding**: Resuscitate cautiously to a target Hemoglobin of **7–8 g/dL**. Avoid high central venous pressure (CVP) to prevent provoking further bleeding.
- **Blood Pressure Tolerance**: Cirrhotic patients often tolerate lower blood pressures (e.g., MAP of 60 mmHg); do not give fluids for mild hypotension unless the patient is in true shock.
- **Volume Depletion**: If resuscitation is truly necessary (e.g., severe GI bleed), **Albumin** is the preferred volume expander over saline to minimize the worsening of ascites.

Summary Mantra: Restrict salt and water; prioritize albumin for complications (Paracentesis, SBP, HRS); avoid saline flooding.

6- Burn Management & Fluid Resuscitation

In the first 24 hours of a major burn (>20% TBSA), massive capillary leak leads to a shift from intravascular to interstitial space. Aggressive, calculated fluid therapy is vital to maintain perfusion.

The Parkland Protocol (First 24 Hours)

- ✓ **Formula**: **4 mL × Body Weight (kg) × %TBSA** of **Lactated Ringer's (LR)**.[4]
- ✓ **Timing**: Administer **50%** in the first 8 hours (from the time of burn), and the remaining **50%** over the next 16 hours.[5]
- ✓ **Fluid Choice**: **LR is preferred** over NS to avoid hyperchloremic acidosis.[6] Avoid hypotonic fluids (worsens edema) and colloids (leak out of capillaries) in the first 24h

6- Burn Management & Fluid Resuscitation

Titration and Goals

- **Target Urine Output (UOP)**:
  - **Adults**: 0.5 mL/kg/hr (approx. 30–50 mL/hr).
  - **Children (<30 kg)**: 1.0 mL/kg/hr.
- **Adjustments**: High-voltage electrical or inhalation injuries often require higher volumes than the standard formula suggests.

6- Burn Management & Fluid Resuscitation

Critical Monitoring & Complications

- **"Fluid Creep" (Over-resuscitation)**: Excessive fluids lead to **Compartment Syndrome** (abdominal or limb) and pulmonary edema.[7] If UOP exceeds targets, slow the infusion.
- **Pediatric Considerations**: Always add **Dextrose-containing maintenance fluids** to the Parkland volume to prevent hypoglycemia in children.
- **Post-24h Phase**: Colloids (Albumin) can be introduced after 24h once capillary integrity restores. Anticipate high ongoing losses due to evaporation from open wounds.

Key Labs: Monitor **Lactate, Base Deficit, and Sodium** levels; physical exams remain the most reliable indicator of effective resuscitation.

7- Diabetic Emergencies: DKA & HHS Fluid Management

1. Diabetic Ketoacidosis (DKA)

- ❑ **Initial Resuscitation**: Start with **0.9% NS** (approx. 1L in the first hour).
- ❑ **The Switch**: After the first hour, assess serum Sodium:
  - If **Na is Normal/High**: Switch to **0.45% NaCl** (250–500 mL/hr).
  - If **Na is Low**: Continue **0.9% NS**.

- ❑ **Glucose Management**: Add **Dextrose (D5½NS)** once Blood Glucose reaches **~200 mg/dL** to prevent hypoglycemia while continuing the insulin drip.

- ❑ **Potassium (K) Vigilance**: Patients are body-depleted of K.
  - if K <5.3; Add 20–40 mEq/L to fluids.
  - If K <3.3: **Hold insulin** and replace K aggressively until it rises above 3.3.
- ❑ **Pediatric Caution**: Correct dehydration gradually over 48h to minimize the risk of **cerebral edema**.

7- Diabetic Emergencies: DKA & HHS Fluid Management

2. Hyperosmolar Hyperglycemic State (HHS)

- **Severe Dehydration**: Deficits are often **8–10 L**. Initial volume needs are massive (4–6L in the first 8–10 hours).
- **Protocol**: Start with **0.9% NS**. Switch to **½NS** once hemodynamically stable or if Sodium is high.
- **Dextrose Transition**: Add Dextrose earlier (at **BG ~300 mg/dL**) compared to DKA.
- **Osmolarity**: Avoid dropping effective osmolarity by more than **3 mOsm/kg/hr** to protect the brain.

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